GENERAL FIRE HAZARDS
AND
FIRE PREVENTION

BY

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PREFACE

THE subject of Fire Hazards and Fire Prevention has always been a prominent one in the curriculum of the student of fire insurance, but, until recently, surprisingly little interest has been taken by other parties With a growing appreciation that all loss by fire is a national loss the subject has now an appeal to a very much wider circle, including personnel of the National Fire Service, fire prevention officers, factory executives, and many others who previously had little knowledge of fire risk.

Whilst the primary purpose of this book is to cover the Chartered Insurance Institute's Syllabus for "General Fire Hazards," it is hoped that it will also be useful to students and members of the Institution of Fire Engineers and to many others who are interested in Fire Prevention. With this objective the various hazards and their means of prevention are presented as simply and concisely as is consistent with enabling them to be thoroughly understood Information, however interesting, which did not seem essential to this purpose has been omitted. Those who desire a deeper knowledge of various aspects will find on p 149 a list of books and published papers, to the authors of which I express acknowledgment of my obligation for information obtained from their work

The problem of deciding how much space to devote to fires caused by enemy action seemed a difficult one, for while in wartime the principal cause of fires is the incendiary bomb, the course of any fire, in war or peace, is not generally dependent so much upon its origination as upon the construction and situation of the building concerned and the use to which it is put. In most respects a fire resulting from an incendiary bomb does not differ from one caused by a discarded cigarette end. The problem has been solved by the timely issue by the Ministry of Home Security of Air Raid Precautions Handbook No. 13, "Fire Protection," which deals authoritatively with measures of protection against incendiary bombs.

My grateful thanks are due to Mr. D Walker, A.C.I.I., who has been good enough to read through the proofs, and to my wife, who has given me considerable assistance.

J. J. W.

BIRMINGHAM

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AND

FIRE PREVENTION

CHAPTER I

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IT has been estimated that the loss of property directly caused by fire in this country is in the neighbourhood of £12,000,000 annually, but this is not the total of the loss To the loss by fire, smoke, and water must be added the consequential loss—the interruption of business and production, and the loss occasioned by injury and illness Although the amounts of these losses are difficult to compute, it is clear that the total is an impressive one

It is not always appreciated that all loss by fire is a loss to the nation When an individual loser is indemnified by insurance the effect is merely to spread the loss over a number of persons, the labour expended in replacing the property is a national loss, as it could otherwise have been employed in adding to the national wealth instead of merely replacing fire wastage. The minimization of loss by fire can, therefore, be regarded as a national duty, and it is surprising that until recently so little effort has been made to reduce this waste Local authorities have control over the erection of new buildings and, through fire brigades, have exercised supervision over places of amusement and public buildings, but elsewhere the only systematic inspections seem to have been those of insurance surveyors Since the Fire Brigades Act, 1938, the outbreak of war in 1939 and the formation of the National Fire Service in 1941, interest in fire prevention has increased tremendously, and various ministries and authorities have appointed their own Fire Prevention Departments

The problems of avoiding the outbreak of fires and of preventing their spread are studied in insurance circles under the heading of "Fire Hazards," but the subject is known to the Fire Service as "Fire Prevention." The two designations are easily reconciled, for without an accurate and comprehensive knowledge

of the hazards involved it is not possible to prevent fires; on the other hand a full knowledge of them usually suggests the remedy.

"Fire Hazards" is a term which includes not only the causes of fires (sometimes called originating risk) but embraces those circumstances which increase the probability of a fire occurring, or which enable or permit fires, once started, to spread and increase the loss (contributory risk). The contributory risk is frequently of greater importance than the originating risk. The cause of a fire is often given as "light thrown down," but it is obvious that the light would not have caused a fire had it not fallen where there was combustible material Had it fallen in and ignited a heap of waste matter the loss would still have been negligible had there been no combustible materials near to extend the fire. Suppose, however, that a lighted match fell upon and ignited a heap of waste rags and shavings which in turn ignited a timber partition against which the waste was stacked, that the fire spread by way of inflammable materials over the whole of the floor and, via open wood stairs, to other floors, until the whole of the building was involved In such a case the loss directly attributable to the "cause of fire" would be negligible, but the features which spread the fire, i e the timber partition, the inflammable stocks, and the open stairs would have increased the negligible loss to a very substantial one. Similarly, fire prevention aims not only at preventing the starting of fires but also at preventing their spreading.

Fire hazards are generally regarded in two categories. firstly common hazards, which are those likely to be found in almost any premises—ordinary everyday risks—and secondly, special hazards, which are those peculiar to or directly associated with particular occupancies. There can be no clear line of demarcation between the two, as processes limited to one trade may in time spread to others, e.g. the use of cellulose solutions was at one time practically confined to makers of "leather-cloth," but cellulose paints are now used in a large variety of trades. The term "General Fire Hazards" embraces such risks in addition to common hazards. Consideration of hazards to life is excluded, yet it is clear that in preventing fires the possibilities of loss of life by fire are reduced.

Causes of Fires

It is difficult to obtain accurate statistics as to the causes of fires, partly owing to the fact that many outbreaks are not observed until so late that the real cause is a matter of conjecture, and partly due to classifications being made under different headings. The Report of the Royal Commission on Fire Brigades and Fire

Prevention summarized the returns of local authorities as to the causes of some 19,000 fires, as shown in the first column of the following table, and the late Colonel Fox, of the London Salvage Corps, in a paper read before the Insurance Institute of London, gave the figures in the second column as those of 3208 fires in London.

Carelessness	3317	1130
Structural defects	2150	240
Lighting	1700	386
Heating	1884	684
In the exercise of business or industry	1958	365
Incendiary or suspicions	1629	5
Other causes	2674	—
Unknown	3636	398

These figures provide food for much thought, but the outstanding feature is the large proportion of fires directly caused by carelessness, especially as it may safely be assumed that many of those recorded as "unknown" and some, at any rate, of those under each of the other headings (with the exception of "Incendiary") were the indirect result of carelessness. This heading embraces the many fires caused by the careless use of matches, indiscriminate disposal of glowing cigarette-ends, smoking in bed, deposit of hot ashes in wood boxes or in unsuitable places, use of petrol for domestic dry-cleaning, use of petrol or paraffin for lighting fires and other purposes, drying of clothes in front of unguarded fires, boiling up fat or floor polish on gas-rings, and a multitude of others, including the traditional sport of hunting a gas leakage with a lighted candle.

Neither of these classifications includes fires caused by enemy action, nor for that matter is the incendiary bomb given any special consideration in this book. Such ample information is published by the Government, particularly in A.R.P. Handbooks Nos. 9 and 13, as to render it unnecessary. Moreover, it must be kept well in mind that while in war-time enemy action is in the forefront of "causes of fire," the same precautions are required to prevent the spread of fires, whether they originate from this or any other cause

A fire started by an incendiary bomb is of the same nature as any other fire, and its course is determined not by the incendiary agent but by the conditions obtaining in and about the building. As A.R P. Handbook No. 9 puts it, "it cannot be too strongly emphasized that the fire started by an incendiary bomb is far more important than the bomb itself." The damage likely to be caused by incendiary bomb fires can be restricted in exactly the same way as "civil" fires, i.e. by the application of the appropriate and generally accepted fire prevention measures. Damage

caused by high-explosive bombs may nullify some of the safeguards

Detection and Extinguishment

Although the problems of fire detection and extinguishment, sometimes referred to as fire protection, are rightly regarded as a subject separate from that of fire prevention, they are closely allied to it, and a few words on these matters are perhaps not out of place It is imperative that provision should be made for early detection and extinguishment as, although once a fire has gained a hold it may so extend as to defy the efforts of fire brigades to extinguish it, yet in the majority of cases a fire can be put out with as little as a glassful of water if only the effort be made soon enough after the inception of the fire. It may be recalled that Shakespeare shrewdly observed "a little fire is quickly trodden out, which, being suffered, rivers cannot quench."

Detection. When watchmen are employed it is desirable that they should be supplied with tell-tale clocks, which provide a check that the men maintain their pre-arranged patrols. The value of a watchman depends entirely on his integrity, and it may fairly be said that a careless watchman is worse than none at all, as he may introduce fresh hazards, such as smoking or preparing meals Too often a man who is unfit for any other work is employed—it may transpire subsequently that he is also unsuitable for this work! It is, of course, necessary that some means be provided of communicating quickly with the fire brigade or other help either by telephone or other suitable means. However good the watchman, he can only be in one place at a time, and there is therefore some delay, depending on the frequency of his visits and the length of his round before he can observe a fire. Automatic alarms are superior, inasmuch as every part of a premises is under observation, so to speak, at all times This does not apply during war, when automatic equipment may be damaged by enemy action

Automatic fire alarms are of varying types, but all automatically give warning of the outbreak of fire or of conditions in which an outbreak is likely An alarm bell is fixed outside the building and the alarm is also given by electrical means to the nearest fire station, thus saving valuable time

Sprinkler installations, which are described on page 6, give an alarm at a gong outside the premises. The disadvantage that they do not operate quite as quickly as electric fire alarms or give the alarm at the fire station is more than balanced by the fact that they immediately begin to extinguish the fire.

Extinguishment. It is idle to detect a fire unless the discovery

is speedily followed up by efforts at extinguishing the outbreak. First-aid appliances are invaluable if used at the inception of a fire, but owing to their small capacity are useless once a fire has obtained a hold. It is necessary, therefore, that they be well distributed throughout the premises in order that prompt use may be made of them, and probably the best method of distribution is to arrange them in small groups near doorways, where they are seen every time a person enters or leaves the premises. It is essential that they be regularly inspected and when necessary refilled, an empty bucket, for example, cannot be expected to prove of any use in extinguishing a fire.

Whatever means of extinguishment are provided, the fire service should be notified immediately an outbreak is observed If the fire can be extinguished by persons already on the premises no harm will be done, but if the fire proves to be beyond the capacity of these parties—and their appliances—invaluable time will have been saved by the early call of the fire brigade. Some of the following first-aid appliances are usually provided at industrial premises.

Buckets of water are not highly efficient, owing to the difficulty of accurately directing the contents at a fire, especially if it be above shoulder level. They have, however, the advantages that they are cheap, that everyone understands their use, and that it can be seen at a glance whether they are in good condition.

Buckets of sand are of value for use on small fires of oils or other fires where water may not be used, but are of little utility for general purposes Sand is liable to cause damage to machinery bearings, and the buckets might often more advantageously be filled with powdered asbestos or asbestos-graphite mixture.

Hand and stirrup pumps enable water to be applied easily and effectively to a fire Many types, however, have the disadvantage that they cannot readily be operated by one person

Soda-acid extinguishers eject by chemical action a jet of water, and are very good for ordinary fires such as rubbish, wood, paper, etc

Foam extinguishers are very efficacious in the case of oil or spirit fires The appliances previously described aim at extinguishing a fire by "cooling" or "striking," but the foam extincteur by "blanketing," i.e excluding air from the fire.

Special liquid extinguishers contain carbon tetrachloride, methyl bromide, or a special liquid which is pumped by hand on to the fire, where it is vaporized by the heat and "blankets" the fire. They are suitable for oil, and especially for electrical fires, as the liquids are non-conductors of electricity, the risk of the operator sustaining a shock, which would be probable were other chemical

extincteurs or water used, is averted They should be used with caution in confined spaces owing to the toxic vapours given off

Carbon dioxide extinguishers are suitable for fires involving inflammable liquids, paint dipping tanks, and elsewhere where a fire can be extinguished by smothering or where water damage would be heavy were water applied

Hose reels with 1 in. hose and $\frac{1}{4}$ in. nozzles always connected to the water main are easily handled and ready for immediate use

Hydrants and motor pumps require trained men for their operation and do not come within the category of first-aid appliances It may, however, be mentioned that where hydrants are provided on each landing of a building it is a good plan to provide a "fire brigade connection" in order that in the event of a failure of the water supply motor pumps can be utilized to pump water into the rising main.

Sprinkler installations are in a category of their own, as they not only give an alarm but automatically attack a fire at its inception.

A sprinkler installation consists of a series of pipes, extending over every part of every storey of a building, and having, at intervals, sprinkler heads so spaced that there is at least one head to every 100 sq. ft. of floor area. A sprinkler head consists of an orifice kept closed by means of a glass valve which is held in position either by a soldered strut or a glass bulb filled with spirit. On a predetermined temperature, usually 155° F, being attained, the soldered strut fuses or the bulb breaks, permitting the glass valve to fall away and water to be ejected as a spray A fire may cause one or more sprinklers to open, but in any case the flow of water through the pipes operates a water motor which rings an alarm gong installed in a prominent position on the outside of the building The efficiency of the sprinkler is amply demonstrated by the fact that insurance companies allow discounts up to over 50 per cent off the premium for first-class installations having suitable water supplies at adequate pressure. It must be appreciated that while the sprinkler head opens automatically on the specified temperature being attained, water will continue to flow until the supply is shut off by hand at the main stop valve It is important, therefore, that the alarm be kept in perfect condition in order not only to give prompt warning of the fire, but so that arrangements can be made to prevent the unnecessary damage which might be caused by water being allowed to continue to flow after the fire had been extinguished. Great care must be exercised not to shut the main stop valve, which is usually situated inside the building near the alarm gong,

until it is certain that the fire has been extinguished. It is also with the idea of avoiding water damage that it is customary to install first-aid appliances, by the prompt use of which it may be possible to extinguish a small fire before the heat is sufficient to cause any sprinklers to open.

Fire brigade connections, which enable motor pumps to be utilized to pump water into an installation in the event of the failure of normal supplies, are sometimes provided. When the normal supply is from the public mains the authorities often raise objections in view of the possibility of the water in the mains becoming polluted by water from other sources.

Moral Hazard

Moral hazard is the term used to indicate the degree of hazard involved in a proposer's personality and in his relationships with others, as distinct from that comprised in the physical features of the premises or goods he wishes to insure.

It is an axiom of fire insurance that any poor physical features can be counteracted by simply increasing the premium, but that, since it is not possible accurately to gauge the measure of the proposer's integrity, or to foretell what will be the reaction of his personality to unexpected misfortunes, the only way in which an insurance office can protect itself where there is good reason to deduce the existence of moral hazard is to decline to entertain the insurance

The crudest form of moral hazard is the likelihood of the insured deliberately setting fire to the premises himself, with the object of making a profit by disposing of obsolete and worthless stock—in American slang "selling out to the insurance company." Lesser degrees of moral hazard are lack of precautions or negligence in preventing a fire occurring, or in not taking active steps to extinguish it once it has started or bad relations between an employer and his employees. These are probably more common forms than that of deliberate fire raising, and, fortunately, some clue to the possession of these traits of character by the occupier can often be found in the appearance of the premises concerned.

CHAPTER II

EXTERNAL CONSTRUCTION

"STANDARD" construction—Walls and roofs, materials allowed and not allowed—Party walls—Structural metalwork, protection

IN order that a comparison may be made of the manner in which varying forms of building construction may be expected to behave when subjected to fire, it is necessary to have a criterion. For this purpose it is convenient to use the rules of the Fire Offices Committee for Standard V Construction (generally spoken of simply as Standard Construction) as this is the type of building most commonly erected and that for which the Fire Offices charge normal rates For buildings of fire-resisting construction (Standards I to IV) varying discounts are allowed off the normal rates, while buildings which fall short of the standard carry a penalty according to the degree in which they fail to conform. It will be observed that rules are laid down only in respect of the exterior, or shell, of the building, no restrictions being imposed as to the internal construction

Any form of construction falling short of this standard is clearly a poor one and is designated "non-standard construction"

STANDARD CONSTRUCTION

RULES OF THE FIRE OFFICES COMMITTEE
FOR
STANDARD V CONSTRUCTION

BUILDINGS TO BE DEEMED OF STANDARD V CONSTRUCTION MUST CONFORM TO THE FOLLOWING DESCRIPTION

DEFINITIONS

Brickwork Solid bricks laid in mortar and/or cement.

Masonry. Stone laid in mortar and/or cement.

Hollow blocks, *Solid blocks*, *Slabs* } Hard blocks of well burned clay or brick-earth, or of cement concrete as defined below.

Concrete. A mixture composed of lime or cement and sand with broken brick, burnt ballast, furnace slag, clinker, other similar hard and burnt material (not including coke breeze), or gravel

NOTE. "Clinker" must not be used as an aggregate in the composition of concrete that is to be in contact with iron or steel.

Cement concrete. A mixture composed of Portland cement or ciment fondu and sand with broken brick, burnt ballast, furnace

slag, clinker, other similar hard and burnt material (not including coke breeze), or gravel.

NOTE. "Clinker" must not be used as an aggregate in the composition of cement concrete that is to be in contact with iron or steel.

WALLS

1. External walls and area walls to be of brickwork, masonry, terra-cotta, cement concrete, hollow blocks, solid blocks and/or slabs

N B Structural iron or steel framework, but not timber framing, is allowed in conjunction with the foregoing materials.

2. Party walls to be of brickwork, masonry, terra-cotta and/or cement concrete and to be not less than 9 in thick of solid material, devoid of cavity, going up to or through the roof

N.B Structural iron or steel framework, but not timber framing, is allowed in conjunction with the foregoing materials provided it be covered with not less than 2 in. of brickwork, masonry, terra-cotta, cement and/or cement concrete.

ROOFS

3 The external surface of the roof to consist of

(1) Slates, tiles, metal, concrete, or asphalt.

N B. Under the term "asphalt" are included compounds, of a minimum thickness of half-an-inch, having a matrix of bitumen or bitumen emulsion with an aggregate or filler of incombustible mineral matter.

(2) Sheets or slabs composed entirely of incombustible mineral ingredients

(3) Bitumen macadam not less than ½-in. in thickness composed of fine gravel or stone chippings and not more than 7 per cent of bitumen.

(4) Layers of paper or felt treated with asphalt cemented together and coated with at least 2 in of sand, earth and/or gravel

(5) Roofing materials set out in the Appendix to these Rules. (The appendix includes the following Cellactite corrugated sheets, Durasteel corrugated roofing sheets, Robertson's asbestos protected metal and Ruberoid insulated steel roof, weatherproofed externally with Astos asbestos roofing)

N.B. Ordinary glass in a roof otherwise conforming to the above is allowed

THE FOLLOWING ARE NOT ALLOWED—

(*a*) *Slates or tiles containing any combustible ingredients.*

(*b*) *A roof entirely of ordinary glass, whether in metal framework or not*

(c) *A lantern-attic or lantern light of glass in timber framework raised above the surrounding roof.*

Considerations of space preclude any detailed reference to building construction, and the following notes refer only to the more important materials allowed and, particularly, not allowed, in "standard" buildings

WALLS

Clearly it is desirable that walls should offer such resistance to a fire, occurring either inside the building or in adjoining premises, that they will not give way and, further, that it will not be necessary to spend large sums in reconditioning them afterwards.

Of the materials allowed, masonry is not so satisfactory as the others. In a serious fire all kinds of stone sustain damage by crumbling or cracking, and the application of water assists decomposition. No thickness is specified for external walls, but it is not to be expected that a wall of 4½ in. brick panels in a steel frame will stand up to fire as well as a 9 in. or thicker wall It will be noted that coke breeze must not be used in concrete as it contains a proportion of unburnt material, and that clinker has an injurious effect on iron or steel The efficiency of concrete depends on the aggregate, i e the material which is mixed with the cement and sand to form the concrete Materials regarded as non-standard in walls include the following—

Timber. Where the walls are constructed entirely of timber it is clear that a serious hazard exists, as all timber is combustible and no effective fireproofing medium has yet been discovered. Timber used in walls varies considerably both as to its nature, whether hard wood or soft wood, and as to its thickness. While it might be argued that walls of thick hard wood have considerable resistance to fire it must be admitted that such walls are seldom found, and that timber walls usually consist of thin boards, such as weatherboarding Where other materials are used in conjunction with timber, the hazard may be somewhat minimized according to the arrangement, proportions, and fire-resisting qualities of those materials, but since timber is a combustible material its presence is always a weakness Half-timbered walls comprise a timber framework filled in with brick, heavy-timber is sometimes used in brick walls for bonding purposes, while old dwellings are frequently constructed of brick on the ground floor but of wood and plaster on the upper floor. Sometimes tiles are hung on the outside of a timber wall or wood and plaster frame, but although the tiles themselves are incombustible, and might protect the timber from an external fire, this is not sufficient, as, in the event

of the frame being consumed, or sufficiently weakened, the whole wall would collapse.

Corrugated iron. This is thin iron sheeting, covered with a zinc coating to prevent it rusting, and corrugated to prevent the sheets bending. It is, of course, incombustible, but owing to its lack of substance it soon expands under the influence of heat sufficiently to tear itself away from its fixings, while if water is applied to it when red hot it crumples up It is necessary to support the sheets on a frame and in buildings intended for more than temporary use it is usual for the frame to be of metal. While this is liable to be damaged in the event of a serious fire in the building, it is, at any rate, better than the employment of a timber frame, which would certainly sustain more damage in similar circumstances, and in addition be liable to damage from a fire occurring outside the building, the corrugated iron being insufficient to protect the wood frame from ignition.

Asbestos cement sheeting. Asbestos is a finely fibrous mineral which is both non-combustible and a very poor conductor of heat. It can be mixed with cement and other ingredients to form rigid sheets ¼ or ⅜ in. thick. These sheets, which are sometimes corrugated, are used similarly to corrugated iron and their efficiency from a fire viewpoint depends upon their composition, some so-called asbestos cement sheeting contains a very small proportion of asbestos They are probably better than corrugated iron, especially in their resistance to a fire outside the building, but have little mechanical strength, are brittle, and disintegrate easily under the effects of fire and water.

Coke breeze slabs are a kind of concrete slab in which the aggregate is coke breeze. They are objectionable inasmuch as a large proportion of a wall constructed of them consists of unburnt material, which in a serious fire is liable to crumble and allow the wall to collapse.

Roofs

The primary object of a roof is to keep out rain and cold, and we might add fire. Roofs of fire-resisting buildings must be entirely of incombustible materials, but for "standard" construction it is stipulated only that the *external surface* be incombustible and not unduly fragile, the object evidently being chiefly to prevent an external fire from entering the building. Thus, any of the allowed materials may be supported on wood boards or battens and rafters, and such roofs are always liable to the risk of collapse in a fire, owing to the wood supports being consumed.

The allowed materials do not call for much comment. Sheets, etc., of incombustible mineral ingredients include the much used

asbestos cement sheeting and tiles, sold also under proprietory names, e g. uralite, poilite, asbestone, etc The fire resistance of the roof depends largely on how the materials are supported, e.g. slates and tiles are fixed on wood battens or boards and supported, as are corrugated iron and asbestos cement sheeting, on wood or metal trusses. Macadam and asphalt are often laid on wood, though they are also used on concrete.

Roofs underdrawn with wood or consisting largely of timber or other combustible material enable fire to spread very rapidly along the roof. The Building Research Board of the Department of Scientific and Industrial Research has recommended that a kind of roof "firestop" should be provided by sheathing a strip of the roof extending across the whole width of the span with light metal sheet or other suitable material to prevent access of air to the timber. Vertical flame screens are added above and below the roof, extending along the centre of the sheathed strip Such devices cannot be expected to be effective in a building containing quantities of combustible material, but in other buildings would, at any rate, provide a point at which fire fighters could concentrate

Of the roofings regarded as non-standard the following are outstanding—

Thatch. A thatched roof, consisting of successive layers of reeds or straw, lends a picturesque appearance to a house, but from a fire viewpoint it is a most hazardous roof It is easily ignited by sparks, possibly from a passing road vehicle, especially in dry weather; it is a good plan to cover the roof with wire netting of small mesh. "Fireproofing" is sometimes undertaken, but the effect soon wears off, due to the weather. Chimneys of houses with thatched roofs should be provided with spark arrestors.

Tarred or bituminous felt is generally laid on wood. It is easily ignited and burns freely. There are many proprietary flexible roofing preparations (e g Ruberoid, Roc, Vulcanite, Pluvex) to replace tarred felt, but they suffer from the same disadvantages, although not to the same extent When used on a sloping roof it is not possible to protect them with a 2 in coating of sand, earth, or gravel as may be done in the case of flat roofs

Timber shingles are strips of wood used similarly to tiles. They are not common in this country, but are freely used in some parts of the world, and serious fires due to their use often occur.

Glass roofs are very fragile and offer little resistance to a fire. Wired glass (see page 32) is permissible, but should be in a metal frame so that the roof will not collapse through the frame being consumed

Lantern lights are skylights raised above the level of the

surrounding roof They are non-standard in timber framework which can easily be ignited from fires in adjacent premises and fall into the building. In metal framework they are standard, but in all cases wired glass is better than ordinary glass.

Wood louvred ventilators present similar risks to lantern lights There are several types of roof deserving special mention.

Belfast roof consists of curved wood lattice girders or trusses carrying a roof of segmented shape, with an external covering of tarred felt or proprietary flexible roofing material, and is objectionable in that the wood lattice girders provide light inflammable fuel while the covering material is liable to ignition from external sources

Mansard roof is a roof having two pitches and, although allowed as standard, is not desirable in congested areas because of the large surface of almost vertical roof, generally slates on timber, making it in some cases little superior to a timber wall

North light, or saw tooth roof. One side of each bay is a long slope and if this is covered with permitted materials the roof ranks as standard The other side, almost vertical and facing north, is of glass Large expanses of glass are never to be encouraged, but if wired glass in metal frames is used there is little objection.

PARTY WALLS

Legally, a party wall is a wall separating adjoining buildings in different ownerships or tenancies. In fire insurance practice it is a separation between "risks," i e the buildings on each side of a party wall are rated independently It follows that a party wall is considered to be something of a fire stop. The insurance specification is given under Standard Construction on page 9, but is capable of division, for, in insurance parlance, a "party wall" is one going up to the roof and a "perfect party wall" one going up to *and through* the roof. It is always desirable that the party wall shall extend through the roof to prevent a fire creeping over the top of the wall

Defective party walls include those of insufficient thickness, i.e. less than 9 in., those which do not extend up to the roof, as in the case of adjoining buildings where the party wall is built up only to the underside of the loft, and those having unallowed openings in the walls. *Holes* of four superficial feet or less to admit shafts, belts, straps, ropes, and steam and gas pipes are allowed, but if there are many such openings the efficacy of the wall is jeopardized, and such openings as exist should be as few and as small as possible *Shafts and pipes* require little space, and should be bricked around closely, while in the case of belt drives it is better to have two very small holes to accommodate the driving and

return portions of the belt, rather than one large hole to accommodate both.

Doorway openings, not exceeding 56 super ft., are permitted only if protected by double "fireproof" doors, fixed the thickness of the wall apart. In a few instances, e.g between single-storey buildings in non-hazardous occupations or sprinklered, single fireproof doors are sometimes permitted. Such doors, which must be constructed strictly to the Fire Offices' Committee Specifications, include iron doors, metal-covered doors, and rolling steel doors, as well as proprietary doors such as Checkfire, Dreadnought, etc It is essential that the doors are maintained in good order and are shut each night.

It will be observed that unprotected structural metalwork in party walls is not permitted

Structural Metalwork

Modern practice more and more inclines to the use of metalwork in the construction of buildings It is frequently employed in steel-frame buildings, in the construction of which a steel frame, or skeleton, is first built up to carry the weight of the floors and roof, and, subsequently, panels of brick or concrete are erected between the steel frame to form screen walls. Even where metal is not used in the walls, steel girders are commonly used for supporting floors, and steel or iron columns and stanchions are freely used

It is true that steel is incombustible and, in this respect, an improvement over wood, although it has often been found that stout oak beams, charred to a depth of one or two inches in a fire, have retained sufficient strength to give support, while unprotected steel girders, by reason of their distortion, have permitted a floor to collapse. It may fairly be said that the fire-resisting qualities of buildings of steel construction depend on the protection of the metalwork, and where suitable and adequate protection is provided there is no doubt that a very high degree of fire resistance can be obtained.

The effect of heat on metal is to cause it to expand. A steel girder 30 ft. long, heated through 700-800° C., would increase about 3 in. in length, and it is clear that in a fire, such a girder, supported and fixed at both ends, would either tear itself away from its fixings or push them apart When cooled the girder would contract, and if this occurred suddenly, as would be the case were the cause cold water from a fireman's hose, it would distort A cast-iron column in similar circumstances would crack. In a building in the construction of which iron or steel has entered to any extent, there is not one but many metal members, and the effect of fire and water, causing some to expand while others

contract, is liable to cause collapse of portions, if not the whole of the structure.

Another hazard is that at high temperature steel loses its rigidity and strength, and a girder, normally more than sufficient to carry the load imposed upon it, may, in a fire, become so weakened as to give way.

Protection of metalwork. To obviate, or at any rate to minimize, these risks it is necessary to protect the metalwork as far as possible from the effects of heat by completely encasing it with protective material, which should be capable of withstanding the effects both of fierce heat and of water poured on it while hot without breaking away Suitable materials for this purpose are brickwork, or cement concrete, and, while difference of opinion exists as to their respective merits, it is probable that cement concrete is the most generally used by reason of its comparative ease of application The fire resistance of cement concrete, the definition of which is given on page 9, depends on the nature of the aggregate, crushed bricks are best.

Other materials used for encasing metalwork are foamed slag concrete, terra-cotta, asbestos (which may be used with cement as a spray) and proprietary slabs, most of which are composed of one of these materials and embody a device for keying or locking the slabs together. Where the Fire Offices' Rules require protection of metalwork a thickness of at least 2 in. is demanded, but it is probable that in many cases a greater thickness would be an advantage. The London County Council have more elaborate regulations.

An additional safeguard against possible damage is to leave spaces in the walls at the ends of metal girders and joists to permit of their expansion.

While it is, of course, desirable that all structural metalwork should be suitably protected, the importance is greatest in connection with vertical members which, too, are the easiest to protect with brickwork or concrete.

CHAPTER III

INTERNAL CONSTRUCTION, SIZE, AND HEIGHT

Floors—Ceilings—Floor openings—Partitions—Wood linings—Concealed spaces—Racks, cupboards, etc —Size—Measures of size—Height

Floors

In judging the merits or demerits of floors there are two main considerations. the materials employed in construction and the existence of floor openings It is highly desirable that floors be constructed entirely of incombustible materials, but if in such floors there be many unprotected openings through which a fire could spread, their efficacy is considerably reduced; in fact it might even be less than that of an unpierced wooden floor, which would check a fire from breaking through for, at any rate, a brief period

Fire-resisting floors may be solid—generally concrete filler-joist or reinforced concrete—or hollow, consisting of varying types of hollow blocks surfaced with concrete. In either case there must be a substantial thickness of solid material and all floor openings and structural metalwork must be suitably protected Details of such floors of a fairly high standard may be found on page 27. In such a building each storey may reasonably be considered a separate "risk"

Non fire-resisting floors generally consist of wood joists supporting floorboards, any ceiling material being attached to the underside of the joists. Often, where appearance is of little moment, as in factories, the floors are not ceiled and are known as open wood-joisted floors. Such floors, if carefully constructed of heavy joists and thick floorboards, afford some resistance, but there is always the risk of flames licking through cracks, caused by age or bad workmanship, between floorboards, and, while a slight improvement can be effected by covering the floor with one of the patent cement compositions on the market, in a fierce or prolonged fire such floors are certain to be destroyed

Ceilings

Various materials are used to provide ceilings to wood floors, and are more or less desirable according to their fire-resisting qualities As, however, they are always fixed to the bottom of the joists, a hollow space, the depth of the joist, is formed between the underside of the floorboards and the ceiling Such concealed

spaces collect dust and possibly oil drippings from the floor above, forming easily inflammable matter, and a fire occurring there is not only difficult to locate and attack but is liable to spread and break out in remote places. There are two methods of treating these objectionable hollow spaces: one is to insert at frequent intervals "stops" of thick boards tightly fitting in the rectangular space formed by the joists, floorboards, and ceiling, but the better is to fill in the spaces with "pugging." Concrete can most satisfactorily be used, but this adds considerable weight and, unless the floor was designed for its use, necessitates special arrangements being made. Foamed slag concrete and pumice concrete are lighter and equally suitable. *Silicate cotton* (or *slag wool*) is a fibrous material, made by blowing steam through the dross produced when pig-iron is made in a blast furnace, and derives its names from its resemblance to cotton-wool. It is light in weight, non-combustible, an excellent non-conductor of heat, and is very suitable for pugging, as it is easily applied. Whatever pugging is used, it should be supported by fillets nailed to the joists so that it will remain in place during a fire. Vegetable materials are sometimes used to deaden sound, but these are objectionable on account of their inflammable nature.

Of materials used for ceilings, plaster is the most common. It is a good non-conductor of heat, and, when keyed on to metal laths or expanded metal, forms a satisfactory ceiling, protecting the wood joists against the heat of a fire in the room below. Unfortunately it is more usual to employ wood laths for a key, and as their fragility renders them easily combustible their use somewhat nullifies the effectiveness of the plaster Another objection is that if the plaster becomes broken in the course of years it leaves the flimsy wood laths exposed

Asbestos or asbestos cement sheeting is sometimes used, and is nailed direct to the joists This obviates the use of laths and may be as good as a plaster ceiling, provided the joints where the sheets butt together are carefully made so that a fire cannot easily creep through

Any ceiling of combustible material is unsatisfactory, whether it be of wood (matchboard), millboard, textile fabric, or paper, as in addition to the hazard of the cavity behind the ceiling, the ceiling itself is easily ignited and provides fuel for a fire. Such ceilings could be improved by covering them with sheet metal or asbestos cement sheeting to protect them from a fire below. Various proprietary ceiling sheetings are manufactured, e g. Essex board, Beaver board, and their suitability depends on their resistance to fire—most of them are combustible and must be regarded as no better than wood

To summarize wood-joisted floors may be divided into three classes open joisted, superior to open joisted, and inferior. Of those superior, plaster on metal laths is the best, followed by plaster on wood battens, plaster on wood laths and asbestos sheeting. In each case suitable pugging or stopping is desirable.

Floor Openings

In order to restrict to the minimum the damage caused by a fire, it is essential to confine it to the floor on which it occurs. Fire tends to spread faster vertically than horizontally, and unprotected floor openings allow flame and smoke to be carried upward from floor to floor, and burning embers to fall to floors below, thus spreading the fire throughout the building. They allow water used in extinguishing a fire on an upper floor to pour to lower floors, adding to the loss directly caused by the fire and, by forming a sort of flue into which fresh air is drawn from all parts of the building and from outside through windows and doors, increase the fierceness of a fire An ideal arrangement would be to have no floor openings, access to the various floors being obtained by hoists and staircases in the open, or in a separate block communicating with the main building only by fire-proof doors, but in the majority of buildings of ordinary construction this is not practicable What should be aimed at is to enclose all floor openings in such a manner as to be at least equal in fire resistance to the floors of the building.

Well holes are serious hazards, as it is not possible to protect them. The name is given to large openings in floors, the roof over usually being of glass in order to provide light to lower floors. An extreme case is where each of the upper floors forms a kind of gallery around the central well, as is often found in drapery and other large stores A fire starting on one floor is almost certain to be speedily communicated to the others

Stairs. Open stairways allow free passage for fire and smoke and, if of wood, supply fuel. An enclosure of light wood is useless, and merely provides additional fuel to the fire. In a wooden-floored (non-fire-resisting) building stairs and enclosures of any of the following materials may be accepted as satisfactory, but failing these, a well-constructed enclosure of any non-combustible material, having doors to all openings, is an improvement over an unenclosed staircase

1. **Steps and landings.** Brick, cement concrete, iron, hardwood.
2. **Enclosing walls.** Brick, cement concrete, or terra-cotta blocks.
3. **Openings to floors from the stairs.** Protected by self-closing doors of metal or hardwood. Hardwood doors should be at least

$1\frac{3}{4}$ in. in thickness throughout, and their frames bedded solid to the walls. Any glass panels in the doors should be of wired glass or electro-copper glazing, and their size restricted. The hardwoods commonly employed in the construction of doors are oak, teak, and mahogany. It is better that there be no windows in the enclosing walls, but if they are necessary they should be of wired glass

Hoists and lift shafts present similar risks to staircases, but, owing to the lack of obstruction in the shaft, a free draught is possible and a fire might spread to several floors at the same time. Lift shafts should be enclosed, and supplied with doors similar to those on stairs.

Both stairs and hoist enclosures should extend from the lowest floor up to and through the roof It is an arguable question whether it is better to have a substantial or a fragile roof. A substantial roof, e g. concrete, prevents the shaft acting as a flue to create a draught as long as the roof remains intact, but the smoke, unable to escape, finds its way into all parts of the building and retards fire-fighting, while a fragile roof of thin ordinary glass, by reason of its early breakage, permits the smoke to escape, but a draught is created which intensifies the fire It appears that while the Fire Offices' Rules favour the use of wired glass the L C.C. prefer a fragile roof with an external wire-netting guard. In either case the damage is likely to be very much less if openings from the enclosure are protected by self-closing doors than if they are not.

Belt and rope holes. These spread fire easily from floor to floor, and if many exist the safeguards provided for stairs and hoists may be nullified by the unprotected holes If possible, belt drives should be enclosed in non-combustible material, and in the case of small drives for light machinery $\frac{1}{16}$ in. thick sheet metal provides an enclosure cheap and easily erected. It is not always practicable to enclose such drives, and in that case all that can be done is to reduce the number and size of such openings to a minimum

Large main belt and rope races should be enclosed in brick towers outside the main building if possible, the openings to the main building being kept as small as practicable.

Spouts and trunks, chutes, conveyors, etc., should have enclosures of sheet metal or metal shutters as the case permits, the object being in each case to restrict a fire to one floor

Chases are channels cut in the walls for gas, water, etc., pipes, the front being enclosed with wood for easy access. Provided a fire stop, e g. concrete, is inserted at each floor level, this convenient method is unobjectionable.

Partitions

Partitions can be regarded as comprising all internal walls or screens dividing up a building into rooms or compartments, as distinct from external or party walls. Partitions can be of great value, inasmuch as if they are constructed of brick or concrete, or terra-cotta blocks, they will tend to confine a fire to the portion of the building in which it originated, or, at the least, will prevent it sweeping through the entire building, as might otherwise be the case. To be of such service, however, they must be of substantial thickness, extend from floor to roof, and have all openings protected with doors, which if not "fireproof" should be about 2 in thick throughout of hardwood. Most modern factory and warehouse buildings have as few divisions as possible in order not to obstruct light and air and to facilitate management, but while this tends to improve the appearance and cleanliness of the premises it entails the drawback that there are no internal "fire-stops" Partitions of combustible material have, from the fire viewpoint, nothing to recommend them, as not only do they fail to hinder a fire but even supply fuel for it, besides providing odd corners in which rubbish may accumulate.

Wood partitions are generally of soft resinous wood, which in the course of time becomes dry and ignites easily. Sheets of mill-board, wood pulp, vegetable fibre, or other combustible material are in the same category Any of these may be improved by covering both sides with sheet-metal or asbestos cement sheeting, and while glass partitions in timber frames are of little use in holding up a fire they provide less fuel than those entirely of wood

Between the desirable brick partition walls and the most undesirable timber partitions there are a large number of different forms, among the best of which are various "slab" constructions The slabs may be of compressed slag wool or asbestos or one of the many patent fire-resisting slabs on the market, while coke-breeze slabs, rendered on both sides with plaster, form good light partitions Other suitable kinds consist of asbestos cement sheeting or plaster on expanded metal supported on and completely covering a timber or, preferably, metal frame.

Wood Linings

Although in most buildings the walls are covered with plaster, yet in many, especially in damp places or where plastering would be liable to sustain damage, wood linings are employed. Generally, matchboarding, which is a light resinous type of wood, is used, and is attached to battens fixed to the wall, leaving an air space or cavity between the boarding and the wall. The risk is

similar to that of wood-lined ceilings inasmuch as a fire spreads rapidly, is difficult to locate and extinguish, and may break out from behind the boarding in a number of places simultaneously. Sometimes wood plugs to which the battens are secured are driven into flues, in which case there is a risk of the plug igniting. Vermin often make nests of inflammable waste materials, and possibly even of matches, behind the linings. Were the wood linings fixed closely against the wall there would be no air space and the risk very much reduced, an improvement can also be effected by completely covering the linings with metal or asbestos cement sheeting.

Cases have arisen of wood linings becoming ignited due to the heat transmitted through a party wall, on the other side of which an intense fire was raging It will be appreciated that such a fire could easily creep through a crack in the brickwork, which would have been observed had the wall not been wood-lined, cracks in flues may, in a similar way, be unnoticed and give rise to fires.

Concealed Spaces

Enclosed attics, roof spaces, spaces above false ceilings and all other concealed spaces are a hazard, as dust and fluff can accumulate and woodwork becomes very dry. A fire can spread easily and rapidly without being observed, and in addition to the loss by fire, damage is unavoidably caused by firemen in their efforts to locate the seat of the fire

Racks, Cupboards, Etc.

The metal racks now often found in industrial premises are a great improvement over wooden shelving which often aids the spread of fire. Cupboards for workmen's clothing should be constructed of sheet metal. Many fires have occurred through hot pipes being left in smokers' pockets, and others through oily waste being allowed to lie in cupboards.

Size

It is an axiom that, other things being equal, the greater the size of a building the greater the fire hazard. Although the principle has been accepted by civil authorities, who impose limits of size by Building Acts and by insurance companies who charge increased rates for very large buildings, the underlying reasons are seldom appreciated by the public

In the first place there is more value at risk in a large building than in a small one Should a merchant's stock be contained in one building it could all be lost in one fire, whereas if it were distributed over a number of buildings remote from one another

only a portion would be destroyed by any fire. Other reasons for regarding excessive size with disfavour are that it is more difficult to locate and fight an outbreak and the possible intensity of a fire is greater in proportion to the size of the building. This point can easily be appreciated by blowing out one lighted candle and then trying to perform the same feat with a group of a dozen.

As long ago as the 'sixties Captain Shaw, then chief of the London Fire Brigade (and immortalized in the Fairy Queen's song in *Iolanthe*), said that "with a well-organized and properly equipped fire brigade, it is found that 216,000 cub ft. is the largest cubical capacity which can be protected with reasonable hope of success after a fire has once come to a head," and in spite of the vastly improved equipment of to-day this opinion is endorsed by all authorities.

The figure of 216,000 cub. ft. represents a 60 ft. cube, i.e a building 60 ft. long, 60 ft wide, 60 ft. high, and is the figure upon which the ordinary limit of 250,000 cub ft. in the London Building Act is based. When a building is of fire-resisting construction, and is divided by good walls vertically and fire-resisting floors horizontally into a number of self-contained compartments, the hazard is considerably reduced, though the size of each compartment should be strictly limited, e g Fire Offices Committee Standard 1 B, Fire Resisting Construction, limits the size to 60,000 cub ft. The Building Research Board recommends compartments with a superficial floor area of not more, and preferably less, than 10,000 sq. ft , which represents roughly the same size.

Measures of Size

The measure of a building in cubic feet, or cubical capacity, as it is termed, is an excellent way of comparing warehouse buildings, where the quantity of goods stored, values at risk and probable extent of a fire are in direct proportion to the size, but it is not so suitable for application to manufacturing and other risks. It might even give misleading results, as in the case of two cabinet-makers' workshops, one smaller than the other but employing more workmen Here it is probable that the larger would be the better risk owing to possible congestion of the smaller and the fact that each workman is a source of hazard in creating more shavings and waste. What is required is a criterion of *fire size,* and it is necessary to apply to different types of risk different criteria, in order to indicate the "fire size," i e. the values at risk, the quantity of materials on or passing through the premises, and, therefore, the probable extent of a fire.

Cubical capacity (or cubical content). This is simply the size of the building in cubic feet, and is ideal for warehouses where the

probable extent and intensity of a fire is directly proportional to the size of the building.

Superficial floor area is a similar measure to cubical capacity, but perhaps more suitable in respect of shed buildings. The larger the area over which a building is spread the greater the difficulty in locating and extinguishing an outbreak of fire. Unless there are effective fire stops a fire can spread throughout the building, and damage by smoke and water also is liable to be extensive. It is possible that in the past insufficient attention has been given to the fire risks of very large one-storey buildings.

Hands. This is the most common measure for factories. It indicates the amount of work done and, therefore, the approximate quantity of materials passing through the factory. In many factories, e g woodworkers, upholsterers, printers, inflammable waste is produced and the more hands the greater is the quantity. Where fires are likely to arise by reason of the kind of work done it is obvious that the greater the number of hands the greater is the risk of a fire commencing.

In saleshops, e.g. drapers, furniture-dealers, the number of assistants is a clear indication of the amount of stock, and, in addition, each employee is regarded as a possible source of danger through his individual carelessness.

Machines. Where machines themselves are liable to cause fires or to give rise to conditions favourable to fire this measure is applicable, e g. sawmills, where each machine adds to the amount of waste produced and is itself liable to cause an outbreak, cotton mills, where the number of spindles indicates the risk from friction and the quantity of inflammable material being worked

Benches. In cabinet-makers, woodworkers generally, and numbers of other risks, the number of benches indicates the "fire size" in much the same way as the number of hands.

Other measures of size are "length of roller contact" in corn mills and "quantity of inflammables" in petroleum stores.

HEIGHT

The hazard of height is often confused with that of size, but it is really quite a distinct hazard. A building small in floor area may nevertheless be several storeys in height, while one having many times the floor area may be of one storey only.

A one-floor building is known as a shed, and a storied building is inferior in several respects. A fire on a lower floor tends to spread upward, and even if the flames do not penetrate to the upper floors there is the probability of smoke damage. On the other hand, water used in extinguishing a fire on one of the upper floors may damage property on those lower, either by flowing

through floor openings or by percolating through floors In the event of one of the top floors being weakened by fire and giving way, additional weight is thrown on the floor below, which, too, may collapse with similar results; moreover, if the floors be of wood they add fuel to the fire.

Fire-fighting is rendered more difficult, not only by reason of the inaccessibility of upper floors, the difficulty of saving lives and salving stock, and the added danger to firemen, but by reduction in water pressure Since water extinguishes fire by cooling and striking it is more effective at a high pressure, and each foot of height reduces the pressure per square inch by nearly half a pound.

Another hazard—mentioned in Chapter V—is that of enhanced exposure risk, especially where the building has many wall openings

Fire-resisting construction obviates some of these hazards and minimizes others, but cannot altogether dispose of the objections to height A fire-resisting shed of moderate size is the ideal building from a fire prevention viewpoint.

CHAPTER IV

FIRE-RESISTING CONSTRUCTION

BRITISH standard definitions materials, elements of structure—Fire-resisting buildings—"Fireproofing" of materials

IT is generally acknowledged that it is impossible to construct an absolutely *fireproof* building as all materials are detrimentally affected in some way or other if they are subjected to a sufficiently high temperature. When, however, only materials having a high degree of fire resistance are appropriately used in the construction of a building, the term *fire resisting* may properly be employed. Statutory regulations control the planning of buildings and demand certain physical qualities having regard to the stresses to which the buildings will be subjected, but until comparatively recently there was no requirement that a certain standard of fire resistance should be attained, chiefly no doubt because no standard tests existed

In 1932 the British Standards Institution issued the *British Standard Definitions for Fire Resistance, Incombustibility and non-inflammability of building materials and structure*, and shortly afterwards the Fire Offices Committee undertook to provide the necessary facilities to enable the standard tests to be carried out This undertaking was implemented by the erection of a testing station at Elstree.

MATERIALS

In connection with materials used for constructive or decorative purposes the term *incombustible* is defined as "one which neither burns nor gives off inflammable vapours in sufficient quantity to ignite at a pilot flame when heated in the manner specified" A small sample of the material is thoroughly dried and then placed in an electrically heated testing tube, where the temperature is increased by 900° F. per hour up to 1382° F. (750° C) The material is not considered to be incombustible if at any time during the test it either flames or glows brighter than the walls of the tube and the glow does not immediately diminish when the specimen is removed from the tube

For some purposes it is sufficient for a material to be non-inflammable—a demand for incombustibility would be too severe Materials which are found to be "combustible" under the definition can be subjected to a further test, in the course of which the material is thoroughly dried and then exposed 1 in above a

test cup containing 0·3 cubic centimetres of absolute alcohol, which produces a flame for about 45 seconds. The material is graded as "non-inflammable," "of very low inflammability," "of low inflammability," or "inflammable," according to the time for which the specimen flames or glows after the alcohol flame has expired and of the extent to which the surface of the specimen is charred, e g non-inflammable material must not glow or flame and the scorching must not reach the edge.

Elements of Structure

The fact that a small sample of a material is found to be incombustible does not necessarily imply that a wall constructed of the material will have a high degree of fire resistance · the material may fail for reasons unconnected with combustibility, e g. it may lose strength when heated "Elements of structure" is the term applied to the principal components of a building such as walls, floors, partitions, beams, columns, and doors, and the tests applied are designed to simulate as far as possible conditions likely to occur in actual fires

The specimens are full size if possible, but if they exceed 10′ × 10′ a representative section is tested · in each case a load 50 per cent greater than that normally carried by the structure is imposed during the tests The specimen is placed in a gas heated furnace and the temperature raised in six hours to 2200° F. the initial increase in temperature being rapid, e g. after 30 mins. 1550° F. is attained. For the higher grades the fire test may be followed by a water test consisting of the application of a ¾ in. jet.

Elements of structure are graded according to the length of time for which they satisfy the requirements These, briefly, are that they remain rigid and do not collapse; do not develop cracks through which flame can pass; the temperature on the unexposed side is not more than 250° F higher than the initial temperature To be graded as *A* an element must satisfy the conditions for 6 hours (maximum temperature 2200° F.), Grade *B* 4 hours (2050° F), Grade *C* 2 hours (1850° F), Grade *D* 1 hour (1700° F), Grade E ½ hour (1550° F.)

Naturally, the cost of erecting a building to conform in all respects to the requirements of the higher grades would be greater than that of less fire-resisting structures and it is reasonable that regard should be given to the nature of the intended occupancy, whether hazardous or not, and the availability of fire extinguishing services in deciding what grade to adopt For non-hazardous occupancies Grade C would often provide reasonable resistance.

It is to be expected that when the Building Research Board is in a position to publish a comprehensive survey of the series

of tests which have been and are being conducted, some modifications in the requirements of various authorities will be made. In the meantime, the following may be regarded as typical of a fairly good class fire-resisting building.

Walls of brickwork, reinforced concrete or stone at least 9 in. thick without cavity. Stone should not be used in party walls, which should extend 18 in above the roof if that of the adjoining building is not of fire-resisting construction.

Openings in external walls. Openings severely exposed to other buildings protected by fireproof doors or shutters or wired glass or electro-copper glazing.

Openings in party walls. Protected by double fireproof doors, i.e. one on each side of the wall Shafting passing through the wall fitting closely, leaving no open space.

Roofs. Brickwork, concrete or hollow tiles covered with concrete at least 3 in. thick. Any skylights of wired glass in hard metal frames

Floors. Solid brickwork arches, solid concrete at least 5 in. thick or hollow tiles with concrete on top, the thickness of solid material being at least 4 in Wood flooring is permissible provided it is laid on the concrete without an intervening space.

Floor openings. Stairs and hoists enclosed by walls of brickwork or reinforced concrete at least 4½ in. thick, stairs and landings constructed of the same materials All openings from the enclosure to other parts of the building protected by fireproof or 2 in. thick self-closing hardwood doors having, if required, small wired glass panels Any other opening suitably protected, e g. holes for steam, gas, and water pipes and electric conduit cemented round the full thickness of the floor, ducts for pipes enclosed similarly to hoists, etc.

Protection of structural metalwork. All structural metalwork, including the framework in walls and that in and supporting floors, completely encased in brickwork or reinforced concrete at least 2 in. thick The thickness of concrete cover to reinforcing bars and rods equal to the thickness of the bar but not less than 1 in.

Partitions and linings to walls and ceilings. Entirely of incombustible materials.

Water damage. To minimize damage by water used for extinguishment, floors should be non-porous, provided with scuppers and have sills or ramps at doorways in party walls

Fireproofing of Materials

There is no method of treating organic substances which will render them entirely incombustible. The term "fireproof" in

connection with fabrics implies that they have been so treated that they will not ignite on coming into contact with a flame, or that if they ignite the burning will not spread—"flameproof" or "fire retardant" are better terms.

Fabrics are dipped in, or, in the case of large articles such as stage scenery, sprayed with, a solution of fire-resisting chemicals. The effect of these when the fabric is heated is to give off inert gases which keep air away from the fabric, or to melt and glaze over the fabric, thus protecting it from the air. Sodium tungstate or ammonium phosphate are often used or a solution suitable for stage scenery is: Borax, 10 oz., boric acid, 8 oz., water, 1 gallon

Wood may be similarly treated with a view to reducing its liability to ignite and of retarding the progress of a fire. Such wood is prevented from flaming, but it will decompose when subjected to heat. The most effective method of applying the solution is by impregnating in a vacuum vessel. The wood is placed in a closed cylinder from which air is exhausted, the solution is then run in under pressure and is forced into the wood. A less efficient method is to immerse the wood in an open bath of hot solution and allow it to remain until cool Various proprietary fire retardant paints are on the market, some made to the British Standards A.R P. formula No 39, which is. Sodium silicate (waterglass) 112 parts by weight, kaolin (china clay) 150 parts by weight, water 100 parts by weight The sodium silicate should be in the form of an aqueous syrup in which the ratio of silica to soda is between 3·2 and 3·4 and which has a specific gravity between 1·41 and 1·43.

CHAPTER V

EXPOSURE

CONSTRUCTIONAL features Areas—Distance from other buildings, gangways, covered yards—Conditions between buildings—Methods of reducing exposure hazard arrangement of buildings, windows, shutters, wired glass, electro-copper glazing, skylights—Drenchers—Conflagration hazard—Isolation

IN previous chapters external and internal constructional features have been examined, mainly in the light of a fire occurring inside the building, but it is necessary also to consider the possibilities of fire spreading from one building to another. The term "exposure" is capable of varying interpretations, but it is most satisfactory to use a wide definition such as "the likelihood of a building or its contents sustaining damage or becoming ignited by reason of a fire in adjoining or neighbouring premises"

There are three main factors in the consideration of exposure hazard· 1 Constructional features 2. Distance from other buildings 3 Conditions existing between buildings.

1 CONSTRUCTIONAL FEATURES

Any non-standard construction (see Chapter II) renders a building liable to be attacked by an outbreak of fire in neighbouring premises, whether it take the form of timber walls or gable-ends, lantern lights, roofings of combustible material, wood louvre ventilators, or any other material in the external surface of the building, e g. wooden eaves, fascia boards, which could be ignited by fire It is obviously necessary that a building should have doors and windows, but from a fire-prevention point of view each one is a weakness as being more susceptible to fire than a brick wall. Many buildings have walls in which the total superficial window area exceeds that of the brick or stonework, and some modern buildings may almost be said to have walls of glass, so great is the window area Such walls greatly add to the probability of a fire breaking into the building, and also permit a fire on one floor of the building to be transmitted to other floors, even though the flooring itself remains intact A flying brand is sufficient to break glass, and radiated heat to melt it, leaving the building open to any chance ember thrown up by a fire.

Unsatisfactory party walls are another frequent cause of fire spreading from one building to another This is not intended to include cases where there are unprotected openings in the party wall—such would be a "communication" rather than an exposure

hazard—but situations where a party wall does not extend sufficiently far above the roofs on either side of it to safeguard one of them from the direct heat and flames of a fire occurring in the other, or is not of sufficient thickness having regard to the occupation of the buildings. It is difficult to specify the distance a perfect party wall should project through the roof, as circumstances vary so greatly, but it may be said that the steeper the pitch of the roof the higher should the wall extend Mansard, Northlight, and Belfast roofs are all susceptible to exposure hazard.

Areas may be described as small open spaces surrounded by buildings In large cities and towns land is expensive and premises are generally erected with as little waste of space as possible In such circumstances detached buildings are rare, and frequently a building is adjoined by other buildings on all but one side, i e the frontage, from which, therefore, all light and ventilation must be derived If the building is at all large it follows that portions remote from the street are poorly served, and, in an endeavour to overcome this disadvantage, small spaces, open to the sky, but enclosed on all sides by the walls of the surrounding structures, are left between buildings Areas form a serious hazard, inasmuch as the walls are weak in a fire sense, owing to the large number of windows and their close proximity to the windows of other buildings. The area acts as a flue, and a fire raging in one building is easily communicated to the others, moreover, a fire may easily be transmitted *via* the area from one to other storeys of a building, even though it has fire-resisting floors. The hazard is greater as the area is smaller, owing to the windows of the several buildings being closer together, and is enhanced if there be any combustible material in the walls. Difficulty of access hampers efforts at fire extinguishment.

Areas common to two or more buildings are known as "common areas," while those which are surrounded by only one building are known as "internal areas" In the latter case a fire will not be transmitted to other buildings, but to other parts of the same building The unfortunate use of the word "internal" to distinguish an area serving one building only, often leads to difficulty in appreciating the difference between an internal area and a well hole The essential distinction is that whereas a well hole is a very large floor opening inside a building, an area is outside the walls of the building and is open to the sky.

2. Distance from other Buildings

Adjoining buildings. Where buildings adjoin, and are the same height, the main risk is of roof to roof exposure, and this is best

combated by party walls extending a sufficient distance through the roof. Where one building is lower than the other there is a possibility of the upper part of the taller collapsing on to the roof of the lower, while if a fire occur in the lower it attacks such windows in the upper floors of the taller as overlook its roof. Buildings adjoining at a corner may have windows in walls at right angles to each other, and such is known as diagonal window exposure.

Buildings not adjoining. It is not possible to lay down any rule as to the distance which should separate buildings in order that a fire in one may not be communicated to the other; each case must be considered in relation to the circumstances It is clear that the more fire-resisting the construction, the less hazardous the occupations, and the less the heights of the buildings, the closer they can, with reasonable safety, be erected. Other factors to be considered are the quality of the water supplies and the time which is likely to elapse before the fire service will be in attendance One of the most obvious risks is that of "opposing windows," and in narrow streets and lanes, such as are often found in old towns, the risk is a very heavy one A fire may readily be extended from one side to the other, due to the breakage or melting of glass There are on record, particularly in America, cases where fires have been started by flying brands in buildings some hundreds of yards distant from the original fire.

Enclosed gangways or bridges between buildings assist in spreading fire, especially if they are of combustible construction. In all cases a metal or hardwood door, preferably self-closing, should be fitted at each end, and no storage of any material whatever allowed in the gangway. Enclosed goods conveyors may form a similar but smaller hazard, and should be supplied with a shutter at each end. Open gangways of incombustible construction are unobjectionable, provided they are kept clear of materials

Covered yards. Sometimes a yard between two buildings is covered in with a light roof of glass or corrugated iron. The exact hazard varies with the circumstances, but it is clear that there is greater risk of a fire being transmitted from one building to another through a covered yard than across an open space The hazard is accentuated if the yard be used for storage of goods or as a standing place for vehicles.

3. Conditions Existing Between Buildings

Although two buildings stand some considerable distance apart, it cannot be assumed, without consideration of the conditions existing between the buildings, that there is no exposure hazard. An engineers' shop may appear to be out of risk of a saw mill

thirty or forty yards away, but if the whole of the intervening space is used as a timber yard a fire in the sawmill might be transmitted *via* the timber to the engineers' shop; a similar position arises where yards are stacked up with barrels or other easily combustible matter. Another circumstance demanding attention is the slope of the ground, for a building might sustain damage by reason of water used in the extinguishment of a fire in another building, at a higher elevation, flowing into it. Burning oils or spirits, from, for example, an oil refinery or a distillery, might float on the surface of the water and thus increase the area of the fire

Methods of Reducing Exposure Hazard

Arrangement of premises. When all the buildings are in one ownership and occupation it is often possible to avoid or reduce exposure risk by segregating a hazardous process or the storage of hazardous goods. The hazardous building should be remotely situated so that in the event of a fire occurring it is not likely to spread to the main buildings

Fire-resisting shutters. These may be of iron or steel, of wood covered with metal, or of steel gauze riveted in a double frame of angle iron There are also rolling steel shutters, which are probably the most convenient form While any of these, if properly constructed, provides very considerable protection to windows, shutters in general are open to several objections They are often unsightly, and if closed at night a fire in the building may burn unobserved by passers-by. If, on the other hand, they are not closed regularly the effects of dirt and the weather may prevent their being closed when required, or the heat from a neighbouring fire may be so intense as to prevent access to them for this purpose.

Wired glass or electro-copper glazing in place of ordinary glass. These forms of window protection, while perhaps not having such great fire resistance as a good shutter, do not suffer from the same objections, as they are always in position to withstand a fire

Wired glass consists of sheets of glass in which wire netting is embedded It withstands great heat, for although the glass may crack it is held together by the wire mesh, and does not fall away. Thus the ingress of flames or burning debris is prevented, or, in the case of a fire already alight in the building, the unbroken windows exclude fresh supplies of air which, if allowed to enter, would assist the fire. The Fire Offices' Rules specify that the glass be not less than ¼ in in thickness, the embedded wire netting not larger than 1 in. mesh, and that the size of each square of glass does not exceed 400 super. in., nor the whole window opening 50 super ft

The glass must be set in grooves secured by hard metal fastenings in frames of hard metal bolted to the wall

Electro-copper glazing consists of small squares of glass united by an electrolytic process with a frame of copper fillets. The Fire Offices' Rules specify that each square of glass must not exceed 16 super. in, and must be at least $\frac{1}{4}$ in. thick. Each sectional light, i e. a number of united small squares equivalent to one pane of glass, must not exceed 4 super. ft. nor the whole window opening 50 super ft. Electro-copper glazing is more expensive than wired glass, and is used where a good appearance is desired.

Skylights. It is possible to give to skylights some protection against flying burning debris by covering them with wire netting, but this is poor protection compared with wired glass set in a hard metal frame The Fire Offices' Rules for skylights are similar to those for windows, but, in addition, the frame must be continuous and divided by bars spaced not more than 18 in. apart. The largest skylight opening deemed capable of efficient protection is 100 super. ft. Electro-copper glazing is not approved for use in skylights, owing to its lesser mechanical strength and its liability to fall in when subjected to great heat.

Doors. Where severe exposure exists doors of softwood should be replaced with hardwood, any glass panels being of wired glass or electro-copper glazing

DRENCHERS

Where very severe exposure exists and it is feared that the ordinary precautions mentioned, i e shutters or fire-resisting glazing, would prove insufficient, drenchers may provide a cure They must not be confused with sprinklers, which are automatic, fitted *inside* a building, and designed to extinguish a fire at its inception, at the same time giving an alarm. Drenchers are non-automatic and aim at preventing a fire in a neighbouring building from damaging the building on which they are installed, by completely covering it *externally* with a water curtain The drenchers are set at intervals of about 8 ft along the apex of the roof, having special regard to skylights, and along the walls, specially placed for windows When required, i e. when there is danger of a fire being communicated from a neighbouring building, a stop valve is opened or, in the case of the automatic type now often installed in London, the sealed drencher heads open at a predetermined temperature Clearly they can be a valuable protection, but there is a disadvantage—they require a lot of water, and if a serious fire is in progress in adjacent premises all available water may be required by the fire service to fight

that fire. In such a case a building relying on drenchers might lose their protection.

CONFLAGRATION HAZARD

A conflagration is generally understood to mean a fire of such magnitude that it involves a number of buildings and is, for a time at least, beyond the control of fire brigades. Apart from the Great Fire of London in 1666 this country has been fortunate in not having suffered, in peace times, conflagrations which have consumed whole towns America has not been so fortunate and, in addition to conflagrations in San Francisco in 1907 and Chicago in 1871, which caused damage estimated at £70,000,000 and £35,000,000 respectively, there have been many fires involving losses of millions of pounds. It is interesting to note that the Chicago conflagration was caused by a Mrs O'Leary's cow, which kicked over an oil lamp, setting fire to its shed, and, in time, to most of the city. Conflagrations are the result of accumulated exposure, generally due to the absence of structural safeguards; narrow streets, excessive height and size of buildings, a strong wind to carry flames and burning debris thrown up by a fire, and a shortage of water The safeguards are the erection of fire-resisting buildings, wide spaces between blocks, and the supply of adequate fire-fighting appliances, personnel, and water. These cannot all be provided by an individual, but, by legislation in the forms of Building Regulations and Town Planning, and in the provision of fire services, much has been and is being done.

ISOLATION

At the other end of the scale are buildings situated in the country, remote from any town. A fire may burn unobserved for a considerable time; it may not be possible to summon a fire brigade easily, and in any case, owing to the distance it would be necessary to travel, the brigade could not be on the spot as quickly as is desirable, also there is often uncertainty of water supplies.

HEATH FIRES

It is a frequent occurrence in hot weather for fires to start on heaths and commons, due perhaps to the sun's rays becoming focused through a broken bottle or to a glowing cigarette end or match. Such fires are often difficult to extinguish or check and buildings adjoining the common may be damaged, especially if they are of non-standard construction.

CHAPTER VI

MANAGEMENT

ARRANGEMENT and condition of premises—Segregation—Supervision—Smoking—Packing materials—Waste—Incinerators—Ashes—Plural tenure—Nightwork and overtime

THE first action of many a fire underwriter in reading the surveyor's report is to turn to the heading "management," and thereafter, in his mind, the whole risk is coloured according to the statement made under that heading. It is difficult to define the exact meaning of "management," but it must include the way in which the business is carried on and the condition in which the premises are maintained—the American term "good housekeeping" is perhaps more expressive. It is dependent upon and reflects the character of those controlling the business, manifesting itself in a number of ways, none of which in themselves may appear vital but in the aggregate enabling a sure estimate of the quality of management to be made The factory reflects the character of those controlling it in the same way as the conduct of the employee matches that of the employer, as the old saying has it, "like master like man."

CONDITION AND ARRANGEMENT OF PREMISES

The general appearance should be clean and tidy Broken electric ceiling-roses or switches, broken gas-light globes, fenders missing from fireplaces or stoves, empty or missing fire-appliances, fireproof doors incapable of being shut, and, of course, any tendency to allow the structure to fall into a poor state of repair are sure signs of lax management, which suggest that other, less obvious, matters are also neglected.

Overcrowding and congestion not only lead to the occurrence of fires, but, owing to the concentration of materials, enable a fire to burn more fiercely, render it more difficult to locate and extinguish, and reduce the possibilities of salvaging stock. A well-arranged factory of suitable size enables workmen to carry on their work in comfort, thereby reducing the risks attendant upon carelessness.

Heavy machinery in a storied building should be situated on the lowest floor, to obviate the possibility of its crashing through floors which may become weakened in a fire. Efficient lubrication and systematic overhaul of all machinery are necessary.

Segregation is an application of the principle of not putting all the eggs in one basket Processes which are known to be liable

to give rise to outbreaks of fire should be carried on either in a separate building or in a portion of the premises bricked off from the remainder, any doorways being fitted with fireproof doors, thus tending to confine any outbreaks to the department in which it originated Similar arrangements should be made for the storage of hazardous goods, only sufficient for one day's use being brought into the factory at a time Even where no hazardous goods or processes are present, use can be made of fireproof doors in substantial partition walls, extending from floor to roof, to divide a premises into more or less self-contained portions Parts used for manufacturing purposes, where fires are most likely to start, should be separated from storage portions, where fires are likely to spread and the loss to be heavy. To be effective fireproof doors must be well constructed, fitted, and maintained, and capable of being closed quickly when required, these necessities are often overlooked

Supervision of Workpeople

Comfortable working conditions are essential—money saved on such overheads as lighting, heating, and ventilation is not economy but parsimony Where the hands consist mainly of young boys and girls, risks arising from inexperience and carelessness arise. Where the bulk of the work is done by pieceworkers it is improbable that the employees will willingly spend time, which might be used in production, in clearing any litter they make. A good manager makes a round of the premises before locking up to see that everything is in good order.

Smoking. Innumerable fires occur through the carelessness of smokers in disposing of glowing cigarette-ends and matches Where combustible waste is made no smoking should be permitted in the factory proper, but it is desirable that smokers be allowed to indulge at suitable times, in a suitable place, such as a mess room If smoking is prohibited altogether there is more temptation to light up when the foreman is absent, necessitating speedy disposal of the lighted cigarette or knocking out of the pipe on his return—in such circumstances the surreptitious smoker is not likely to exercise much care that the glowing fragments do not fall amongst combustible matter It is important that an ample number of suitable receptacles for matches, cigarette ends and ashes be provided

Packing Materials

Owing to the differences in the nature of articles requiring the use of packing materials to protect them against damage, the materials utilized vary very considerably.

Apart from paper and cardboard the materials most commonly used are straw, shavings, and woodwool (wood torn in shreds), all of which are inflammable They should be kept in special bins or compartments in order that so far as possible the packing material shall be confined to one place Where large quantities are necessary, a good arrangement is to keep the bulk in an outbuilding, the bins in the packing room being replenished as required A separate packing room should be provided, partitioned off from the remainder of the premises with non-combustible material, in order that the fragments of packing, which inevitably fall and accumulate on the floor, can easily be swept up This should be done at intervals during the day, and, most important, before the premises are left at night, the floor sweepings being either removed from the premises or returned to the bins. Any open fires or stoves should be supplied with fine-mesh stout wire guards. Similar precautions should be observed in upholsterers' shops and other places where fibrous materials are used

WASTE

In a well-managed factory the floors are swept clear of rubbish and of trade waste at the end of each day's work, if only for the sake of appearance and of having the premises shipshape for the next day This is a sign of good housekeeping, to be commended even if the waste produced is incombustible, but often enough the waste is far from harmless, especially when it is allowed to accumulate under benches or machines, in dark corners, under stairs, in cellars, and other spots not easily accessible for cleaning

Floor-sweepings include rubbish common to all types of premises, e g paper, rags, matches, fragments of packing materials, etc , and, in addition, the waste produced by the particular processes carried on Sometimes such trade waste is of value, in which case it is probable that arrangements are made for its collection and sale, but in other cases it is valueless and, indeed, involves expense in its disposal As waste consists of small fragments it is generally inflammable and often, especially if oily, is liable to spontaneous combustion In such cases the matter should be placed in metal bins with tight-fitting lids to exclude the air necessary for combustion and removed from the premises frequently, because the longer the waste is allowed to lie the greater is the possibility of self-ignition

In some risks, such as mass-production cabinet-makers and upholsterers, boys are continuously employed during the day cleaning up the floors This is an excellent arrangement, but often the difficulty arises that, as the boys cease work before the

workmen, the accumluated waste of the last hour's working is not removed that night.

In other factories waste is removed from machines by air current and delivered through metal trunking to a collector, which should be situated outside the building In such premises a duct to which all floor refuse may be swept can be provided at floor level and connected to the main trunking. See Ventilation, p 103

Whatever the nature of the waste or the method of its collection it is a *sine qua non* that it should be removed from the buildings at the end of each day, in order that the premises be left clean at night. It can be packed in sacks and placed in a detached shed to await collection, or it can be burnt If the works boiler is utilized for this purpose, care must be taken in the arrangements for storage prior to burning, but it is more satisfactory if a good incinerator be used

Incinerators. The name "incinerator" is applied to vastly different forms of apparatus for burning waste and rubbish, from a few sheets of corrugated iron placed around a bonfire—a form which should not be tolerated—to an erection of brick or concrete with a proper firing-place and flue The essential requirements are that burning fragments of waste cannot be emitted and that the apparatus be so situated that there is no combustible material near it

Fire hazards of trade waste. Examples of the waste found in a few types of risk are given below

Textile mills. Easily inflammable. If soaked in vegetable or animal oil liable to spontaneous combustion

Printers. Paper clippings are easily combustible Oily rags or wipes used for cleaning type are contaminated with printer's ink, and are liable to spontaneous combustion. Rags or wipes soaked in oil or spirit for cleaning purposes are inflammable.

Sawmills and woodworkers generally Shavings are inflammable, and all wood waste easily combustible Sawdust may be oily, and if vegetable oil is used for lubrication, liable to spontaneous combustion

Boot and shoe factories The waste is inflammable and some, clicking board scrapings, liable to spontaneous combustion

French polishers. Rags soaked in spirit polish are inflammable; those soaked in oil varnish liable to spontaneous combustion.

Shirt and collar factories Fabric clippings are easily combustible Celluloid stiffeners for soft collars are highly inflammable. Wherever celluloid is used any clippings or waste should be kept separate from the general waste.

Almost every trade produces some hazardous forms of waste,

even fish-fryer's shops—greasy paper and pan scrapings which are not only inflammable but liable to spontaneous heating, as the cottonseed oil in which the frying is done is a drying oil Wherever machinery is used lubrication is necessary, and oily wipes are liable to accumulate These are easily combustible and possibly liable to spontaneous combustion; metal bins with lids should be provided for the temporary reception of the wipes prior to removal

Ashes. These may perhaps be considered a form of waste. It is not sufficient merely to remove them from the premises and dump them in the open, where a wind may fan them into incandescence and scatter them in all directions. A proper bin or pit with a lid should be provided, either of brick or metal, situated well away from combustible material Many fires have been caused by the deposit of ashes, either in carelessness or because they were thought to be cool, on wooden floors or in wooden receptacles, in well-managed factories ashes are usually well damped before being deposited in a safe place

PLURAL TENURE

The great objection to buildings let off to two or more tenants is that there is no unity of control, and, as in other matters, things that should be everybody's business become nobody's business. In a well-managed factory in one occupation arrangements are made for regular removal of waste and pride is taken in keeping the premises clean and tidy, but where no one is in charge of the whole building the maintenance of safe conditions is often neglected, fire appliances are apt to deteriorate, waste is liable to accumulate in odd corners, and the tendency is for each tenant to leave the clearing up of stairs, passages, etc , to others Of several tenants one is sure to have low standards and as the strength of a chain is its weakest link, so the standard of management must be considered that of the worst tenant Instead of lighting, heating, and power being systematically arranged, each tenant may have different forms, and the hours of starting and stopping work vary, with the consequence that the building is in use for more hours than would otherwise be the case Where part of the premises is used as a factory and part as warehouse, there is a combination of originating risk in the factory with the likelihood of high values in the warehouse

These objections are applicable to all buildings in plural tenure, but where different trades are carried on the risk is accentuated and, in buildings in which a large number of tenants carry on different trades (known as omnibus risks), it is impossible accurately to gauge the hazard Some trades employ a cheap, unskilled

class of labour, and the risk of carelessness is enhanced, while other trades, e g. furriers, largely employ foreigners and have an unenviable reputation.

NIGHTWORK AND OVERTIME

Nightwork is defined as work at any time between 9 p m and 5 a m. In some trades, e.g glassblowers, maltings, corn mills, it is either a necessity or facilitates the processes. In many others the tendency is becoming more pronounced owing to the high cost of modern machinery, which in a short time may become obsolete owing to even more efficient machines being manufactured. Overhead charges, including upkeep of premises and depreciation of machinery, are little increased by working twenty-four hours a day and in trades in which the cost of labour does not form too large a proportion of total outgoings, goods can be produced more cheaply by adopting a two- or three-shift day.

It is sometimes asserted that nightwork so far from being a hazard, is a safeguard against fire, inasmuch as there is always someone on the premises to observe a fire at its inception, and to extinguish it before it gains a hold While this is to an extent true, it is in the main a fallacy. It can hardly be disputed that a working factory is a greater risk than a silent one, and when nightwork is in progress the factory may be working for three times its normal period per day with a corresponding increase in the use of lighting, heating, power, and the extended risk of fire arising from trade processes. The continuous use of machinery does not give it opportunity to cool off, thus increasing the risks of friction and overheating bearings, and repairs are apt to be more hurriedly and less efficiently done if work is being held up while the machines are out of use than if they were, in any case, to lie idle until the next day. Carelessness is thought to be more prevalent at night than in the day, and, as has been pointed out elsewhere, carelessness probably causes a larger number of fires than any other single cause. Strict supervision and regular inspection and lubrication of machinery and plant generally—in short, good management—are the only safeguards

Overtime is a similar hazard, but with the difference that instead of a fresh shift coming on duty at regular intervals the staff consists of tired workers—and a tired man is a careless man A point which might be urged in its favour is that overtime suggests prosperity—and a prosperous factory is usually very anxious to avoid delays in output such as would necessarily be caused by a fire

CHAPTER VII

COMBUSTION AND SPONTANEOUS COMBUSTION

COMBUSTION How initiated—Spontaneous combustion—Vegetable and animal oils—Oily waste—Charcoal—Dried wood—Lamp-black—Coal—Hay and other fibres—Other substances

COMBUSTION

Combustion (or fire) is a chemical reaction—the combination of a substance with oxygen, by reason of which heat and light are evolved. The chemical action involved in the rusting of iron is similar to that of the burning of wood—in each case the substance oxidizes (combines with oxygen), but while with iron the reaction proceeds so slowly that the energy set free in the form of heat is dissipated without being observed, in the case of wood the energy liberated shows itself as flame and heat Combustion is popularly taken as meaning this active or flaming combustion, but it must be borne in mind, especially when considering spontaneous combustion, that this is only a similar, but much faster, form of oxidation than that of iron rusting. The lowest temperature at which this *active* combination of a substance with the oxygen of the air takes place is known as the ignition point, and varies very considerably with different substances If for any reason the temperature falls below this point, e.g if water be applied, the reaction ceases—the fire is extinguished The commonest way of supplying the necessary heat to initiate combustion is by application of a flame, but this is not the only way. The heat may be provided by—

Conduction, e.g. woodwork against a stove or stove pipe

Radiation, e g. sun's rays focused through glass, or heat radiated from a neighbouring fire igniting doors or window-frames

Friction, e.g. overheated bearings.

Compression, e.g air-oil vapour in a compression ignition engine.

Lightning. See Chapter XIX

Electric spark, e g. arc due to short circuit or to static discharge.

Frictional spark, e.g. in rag grinding machines

Spontaneous heating. See later pages.

In any case the substance will ignite as soon as its ignition point is reached, no matter by what means, provided there is an adequate supply of oxygen. The ignition point of a particular substance is affected by its condition and its form, if it is dry it ignites more easily than if it is damp, the finer the state of

division the more easily it ignites, owing to the greater surface exposed to the air, enabling oxidation to proceed more readily.

To initiate combustion three things are necessary—

1 A substance capable of combining with oxygen, i e a combustible

2. Oxygen, generally but not necessarily from the air.

3 Heat to raise the temperature of the combustible, or some part of it, to the point where vigorous combination begins to take place

In practice the oxygen is generally supplied from the air, which may for this purpose be considered as oxygen 21 per cent diluted with nitrogen 79 per cent, and the combustion is the more fierce as more air is supplied For example, a dull fire in a grate may be made to burn fiercely by supplying more air by means of a pair of bellows, or the same result occurs if oxygen be supplied in any other way, e g. certain substances, notably the chlorates and nitrates of soda and potash, include oxygen in their composition, and liberate it freely in the presence of heat. On the other hand, if the supply of oxygen be stopped the fire ceases to burn, for the reason that there is no oxygen with which the combustible can combine. Most materials will cease to burn if the oxygen content of the atmosphere is reduced below about 15 per cent, but some will burn so long as there is more than 6 per cent.

Before combustion can begin, heat is necessary to bring the combustible to the temperature at which active combination with oxygen takes place, i e at which it ignites. It is not generally necessary to heat the whole of the substance to this temperature, for as soon as one portion of it ignites the heat of the reaction is sufficient to raise the temperature of an adjoining portion so that it too ignites, and so on until the reaction has spread through the whole, i e it has oxidized or burnt.

Spontaneous Combustion

It must be remembered that whenever oxidation takes place, heat is generated and that at a certain temperature, different for different substances, oxidation proceeds so rapidly that the substance ignites, i e visibly burns. Generally, it is necessary to supply heat from an external source in order that the ignition temperature can be reached, but with certain substances combustion can occur without heat being supplied externally. In other words, the substance, by reason of its own properties, generates sufficient heat to bring itself to its ignition point. A familiar example is the ignition of rags soaked in linseed oil. Oxidation of the oil, commencing at ordinary temperatures,

produces heat and, as any chemical reaction is accelerated by a rise in temperature, so oxidation proceeds more rapidly with another rise of temperature, and so on, until finally ignition point is reached and the rags fire. Differences of opinion exist as to the exact course of events leading up to the spontaneous ignition of different substances, but it can be accepted that, in almost all common cases, the substance is a combustible one which is brought to its ignition point by slow oxidation, the circumstances being such that heat is produced more rapidly than it can be dissipated Where the differences arise is in the means by which oxidation commences, and these can be considered under three main headings—

1. Slow oxidation, commencing at ordinary temperatures, e.g. oily waste.
2 Absorption of oxygen from the air by porous substances, e.g. coal.
3. Action of bacteria, e g hay.

1. Heating due to Slow Oxidation Commencing at Ordinary Temperatures

This includes what, in practice, is one of the most important examples of spontaneous combustion, i e. oily waste, because the danger is not always recognized Oils may roughly be divided into three classes mineral, animal, and vegetable, and, of these, mineral oil is not liable to spontaneous combustion Most animal and vegetable oils will take up oxygen from the air, and according to the amount they will absorb so are they more or less hazardous Some vegetable oils possess this property to such an extent that they are known as "drying oils," the word "drying" implying not that they evaporate like water but that they absorb oxygen, or oxidize, forming a skin or solid substance. They are, therefore, useful as paint and varnish vehicles, the dried skin forming a protective and decorative coating to the article painted On account of its high drying properties, linseed is the oil most used for this purpose, and, for the same reason, it is the most hazardous

When spread over a large surface, as in painting a door, the heat incidental to oxidation of the oil is dissipated by conduction and radiation as quickly as it is generated, and so does no harm If, however, the same quantity of linseed oil is contained in a mass of porous combustible material, e g oily cotton waste, the heat consequent upon oxidation cannot escape so readily, and causes the temperature of the oily mass to rise. This enables oxidation to proceed more rapidly, causing another increase in temperature. So the process continues, oxidation of oil, heat generated and

imprisoned, rise in temperature, accelerated oxidation, until the ignition point is reached and the waste fires. The process takes place without any external aid whatever, and is due solely to the oxidation of the oil, slowly at first but more quickly as the temperature rises There are, however, circumstances which may have a bearing on the matter. It will readily be perceived that if the oily rags are near some source of heat, such as hot-water pipes, the danger of ignition is greatly increased, because, not only is the heat generated unable to get away, but additional heat is supplied by the hot-water pipes. On the other hand, if the heat, by some means, is dissipated as quickly as it is generated the temperature never reaches ignition point.

In the example given, linseed oil and cotton waste have been mentioned, as this is the most hazardous combination, on account of the great "drying" properties of linseed oil and the loose cellular nature of cotton waste, which traps a large amount of air, from which the oil can take up oxygen, and is, in itself, highly combustible.

Other drying oils are hempseed, cottonseed, tung, and poppy-seed oils, but any vegetable oil, e.g almond, olive, or animal oil, e g cod-liver, whale, seal, neat's-foot, is liable to spontaneous combustion for the same reasons, although not to such an extent as the "drying" oils. All must be regarded with suspicion when in conjunction with easily combustible porous matter, such as textile waste, cotton, wool, jute, or sawdust, and wherever such waste is liable to arise, e.g printing works, textile mills, linoleum factories, boot factories, paint or varnish manufacturers, metal bins, with well-fitting lids, should be provided for its temporary reception, and such waste removed from the premises or burnt at the end of each day. Polishing mops left in cupboards have been known to ignite for similar reasons

2 Absorption of Oxygen from the Air by Porous Substance

In this group a number of carbonaceous substances are included—coal, charcoal, lampblack, dried wood

Charcoal is prepared by heating wood without access of air. It is very porous and its commercial value is due largely to its property of absorbing large quantities of gases. When freshly prepared the pores are empty and the charcoal is capable of absorbing about ten times its own volume of oxygen from the air The oxygen, therefore, is contained in about one-tenth of the space it would normally occupy, or, in other words, is compressed or condensed in the pores of the charcoal. Whenever a gas is compressed, heat is generated, and the heat in this case may be sufficient to induce slow oxidation of the charcoal. The oxidation

generates more heat and, as the temperature rises, proceeds more rapidly until finally ignition point is reached.

When the charcoal is several days old the risk is slight, because the pores become filled with moisture and cannot absorb oxygen, but if it be "revivified" by drying out the moisture the risk again exists. If the charcoal be broken up a greater surface is exposed to the air and the danger intensified.

Dried wood. If wood is subjected to heat for a prolonged period (especially alternate heating and cooling, as is the case with wood too near a stove or baker's oven) it chars into a condition resembling charcoal and then may be liable to ignite spontaneously. The process is described on page 67.

Lampblack is a powder used chiefly as a black pigment and is made by burning oil or fat in a poor supply of air. It is liable to spontaneous ignition for similar reasons to charcoal, but, owing to its fineness, the risk is greater As with charcoal, it is more hazardous when freshly made or ground or if stored in large heaps. Should it be dried, after getting damp, it is liable to ignite, even through lying in the sun. An additional hazard is that should a drying oil, even in the smallest quantity, come into contact with lampblack, oxidation is initiated rapidly and the risk of spontaneous ignition is very great.

It must not be overlooked that even in the course of its manufacture lampblack of oil origin may become contaminated, a risk which does not exist with *carbon black or gas black* which is obtained by burning petroleum gases instead of grease or oil

Coal is largely carbon, and the course of events may be similar to that described under charcoal, i e. the coal condenses oxygen on its surface and the warmth generated induces oxidation Greater heat is thus produced and chemical changes take place in the coal, rendering oxidation easier. As the temperature rises oxidation proceeds more rapidly until ignition point is reached

It is accepted that the softer and newer the coal the greater the absorption of oxygen and, therefore, the liability to spontaneous heating—a hard coal, e g anthracite, being the least liable. The smaller the individual pieces of coal the greater is the total surface exposed to air and therefore the greater the hazard—coal dust and pulverized coal are very hazardous. In high stacks the pressure tends to break up the coal forming the lower layers, and the larger the stack the more difficult it is for the heat generated to escape. It is sometimes thought that damp coal is more liable to spontaneous heating than dry coal, but there is no conclusive evidence of this, nor of the theory that coal containing pyrites (iron sulphide) is especially prone because of the liability of the pyrites to oxidize rapidly, generating heat, which

may raise the temperature to the point where the coal itself oxidizes.

Precautions Stacks should not be over 10 ft. in height (8 ft. for slack), nor should there be more than 500 tons in any stack. The coal should not be piled near a chimney or other source of heat, for the higher the temperature the more danger of oxidation. Stacks should be built up of layers 2 to 3 ft. thick, a period being allowed between the stacking of each layer to allow any heat generated to escape easily. If the coal is all in large lumps, so that there is ample ventilation, heat will be dissipated without danger; care should be taken not to break up the coal more than can be avoided, as fine coal in pockets of air between large lumps is most hazardous. Ventilating shafts are sometimes recommended, but this is a dubious expedient, as if not completely efficient this provision may produce just that dangerous state when there is sufficient air to enable oxidation to proceed rapidly, but not enough to carry away the heat produced.

Temperature testing Hollow vertical metal tubes should be placed in the stack at intervals of, say, 20 ft, in order that a thermometer can be lowered twice a week to ascertain the temperature—the maximum is usually about 3 ft. from the bottom Should the temperature at any time exceed about 90° F. a daily reading should be taken and in the event of the temperature rising much above 100° F. it is necessary to break up the stack, as a rule water should not be applied to a stack in which heating has occurred A simpler but less satisfactory method of temperature testing is to insert a metal rod, either specially constructed with a thermometer enclosed at its end or a solid rod which the watchman can feel with his hand

3. Action of Bacteria Leading to Oxidation

Hay. When hay is stacked green, or in a damp condition through dew or rain, it is liable to spontaneous heating. The exact course of events is the subject of various theories, but it is generally thought that the heat produced by unripe seeds ripening or germinating, the continued respiration in the vegetable cells and bacterial action or fermentation is responsible for raising the temperature to a point (probably about 150° F.) sufficient for chemical changes to take place in the hay, producing charring.

The carbon so formed absorbs oxygen in a similar manner to charcoal, and oxidation proceeds more and more rapidly As soon as a free supply of oxygen is obtainable, either by the smouldering portion creeping to the outside of the rick or owing to the rick being broken open in an endeavour to cool it, the hay bursts into

flames. Probably a complete preventive measure would be to stack and keep the hay perfectly dry, but this is not always practicable, though now that artificial crop driers are becoming more common it should not present so much difficulty as in the past. Sometimes, at the time of stacking, vertical air shafts are provided in the rick with the object of removing heat as quickly as it is generated, but it must be emphasized that imperfect ventilation is worse than useless, inasmuch as it supplies air to carry on the process of oxidation.

Other vegetable fibres, if damp, are liable to self-heating, but, as they do not pack so tightly and are generally tougher than hay, the risk of actual ignition is less.

Hemp, jute, and flax are the most prominent and are liable to spontaneous ignition if damp or oily with animal or vegetable oil. Bags made of jute are used for containing nitrate of soda, and when empty are dangerous, as some of the nitrate clings to the bags and, by its readiness to supply oxygen, increases the probability of an outbreak.

Cotton, although it will heat if packed damp, does not ignite spontaneously from this cause, but if oily is the most hazardous fibre.

OTHER SUBSTANCES

Some other substances are spoken of as liable to spontaneous combustion.

Phosphorus will ignite at about 120° F., and if exposed to air at ordinary temperatures the heat of oxidation will generally raise the temperature of the phosphorus to its ignition point.

Metallic potassium decomposes water and the heat of the reaction ignites the hydrogen given off.

Metallic sodium reacts similarly with hot water.

Quicklime, when slaked, i e. brought into contact with water, evolves sufficient heat to ignite any easily inflammable materials near it, e.g. straw or sacking. The lime itself is incombustible.

Chemical reactions involving ignition occur when various substances are brought together, but it is doubtful whether these can be regarded as "spontaneous" and their study is more appropriate to a textbook on chemistry than to this general survey of those commonly found substances which are liable to spontaneous ignition.

CHAPTER VIII

INFLAMMABLE LIQUIDS, VAPOURS, AND GASES

FLASH point of inflammable liquids—Ignition point—Inflammable gases and vapours—Explosions—Precautions—Inflammable liquids—Extinguishment of oil fires

FLASH POINT OF INFLAMMABLE LIQUIDS

IN order to compare the relative fire hazards of inflammable liquids, it is necessary to know their flash points. Flash point is the lowest temperature at which an oil or spirit gives off an inflammable vapour in quantities sufficient to form an ignitable mixture with air, i.e. the temperature at which it begins to be dangerous, because it is the vapour, and not the liquid itself, which ignites Different results are obtained by different methods of testing, but the usual method, and that laid down in the Petroleum Acts, is the use of the Abel apparatus, which comprises a closed cup, in the top of which is a small opening fitted with a lid The oil under test is heated through one degree at a time and tested by opening the lid and applying a standardized flame. The lowest temperature at which a flash or slight explosion is obtained is the flash point At all temperatures above this, inflammable vapours are given off more and more freely. Thus, while it is unlikely that a liquid with a flash point of 100° F. will give off inflammable vapours in this country unless artificially heated, a liquid having a flash point of 50° F. will do so freely most of the year. Such vapours, especially if heavier than air, as in the case of petrol vapour, may drift or migrate a considerable distance before encountering a flame, or other source of ignition, where the stream of vapour may be ignited and the flame flash back until it reaches the source, at which point an explosion may occur.

There are very great differences between the flash points of different liquids The approximate flash points (various authorities give widely differing figures according to the method of testing adopted) of some of those commonly found are as follows—

Ether (ethyl ether) .	− 40° F
Carbon disulphide. . . .	− 22° F
Petroleum spirit . .	− 20° F
Methylated spirit . . .	35° F
White spirit . . .	80°–90° F
Paraffin, kerosene . .	80°–100° F.
Turpentine	100° F
Lubricating oils . . .	350°–500° F.

See also page 60.

Ignition Point

This is the temperature to which an inflammable mixture, or a portion of it, must be heated before the constituents will react and continue their reaction after the source of heat has been removed The heating may be brought about by a flame, contact with a heated surface, or by other means, but as soon as ignition point is reached, active combustion ensues. The ignition point of a liquid varies with circumstances, but is always a very much higher temperature than the flash point

Inflammable Gases and Vapours

Strictly speaking, a gas is a body, which, at ordinary temperature and pressure, exists only in a gaseous state, while vapours are gases given off from certain bodies when they are heated, but which, at ordinary temperature and pressure, are liquids or solids. Inflammable gases include acetylene, carbon monoxide, coal gas, ethylene, hydrogen, methane, and inflammable vapours the vapours of acetone, alcohols, amyl acetate, butyl acetate, benzene, carbon disulphide, ether, naphtha, petroleum spirit, paraffin, etc The term "gas" is frequently used to include both groups Inflammable gases and vapours may be said to be those which will mix with oxygen (or air, as air can, for this purpose, be considered as 21 per cent oxygen diluted with 79 per cent nitrogen) to form an explosive or inflammable mixture, and it may be stressed that it is the combination of the two gases which brings about combustion, neither gas will burn alone.

Hydrogen is a convenient gas to take as an example, as it is typical of inflammable gases It is, with oxygen, a constituent of water and, if heated to a sufficiently high temperature in contact with oxygen, or air, burns with a hot, almost invisible, flame, producing in its union with oxygen water in the form of steam. If a flame be applied to the mouth of a vessel filled with hydrogen, the gas burns only at the mouth, i e. where it is in contact with air, and if a lighted taper be pushed inside the vessel it is extinguished, owing to the lack of oxygen or air with which the hydrogen can combine If, however, hydrogen and oxygen are thoroughly mixed, combustion begins at the point where the flame is applied, and spreads wherever hydrogen and oxygen are in contact, i e. throughout the mixture, with rapidity. Consequently there is a great development of heat, producing sudden expansion, both of the gases and of the product of their combination—steam This sudden expansion drives back the surrounding air in all directions—this is an explosion.

Explosions. Such an explosion may occur whenever there is a mixture of two gases whose combination develops heat, but

the ordinary laws of combustion apply. The temperature of a portion of the mixture must be raised, by some means, to its ignition point before combination will take place, and even then, for the combustion to continue, it is necessary that the temperature produced by the union of the gases in this portion shall be *more than sufficient* to heat adjoining portions to ignition point If the heat produced is only just sufficient to raise the temperature of adjoining portions to ignition point, combustion will continue, but slowly, i.e. the mixture will burn but not explode, and if the heat is not sufficient to raise to ignition point the temperature of the adjoining portions, the reaction will cease altogether.

Bearing in mind that the product of hydrogen and oxygen is water, and that their proportions in a molecule of water are 2–1 by volume, it is reasonable to suppose that the most active combination (i e combustion) will occur when the mixture comprises two volumes of hydrogen and one of oxygen. This is true, and such a mixture is highly explosive An excess of either gas means that some of that gas will be unable to take part in the reaction, and will therefore act as a cooling agent and slow up the reaction by preventing adjacent layers from being heated sufficiently. Thus, if the mixture comprises twelve volumes of hydrogen and one of oxygen, ten volumes of hydrogen will not be used and will slow up the action so that, instead of an explosion occurring, the mixture will burn If a third gas, unable to take part in the reaction, be present it will have a similar effect, and this is the position when air instead of oxygen is mixed with hydrogen; the nitrogen in the air is inert, and reduces the explosive and ignition limits.

For practical purposes, it is more convenient to consider the proportions of inflammable gases mixed with air than with oxygen; the following table gives the proportions in which various gases and vapours must be mixed with air to provide an inflammable mixture. It will be appreciated that the wider the range the greater is the likelihood of an inflammable or explosive mixture being formed. The maximum effect of the ignition will only be obtained when the gases are mixed in a fixed proportion, which is sometimes called the explosive zone (e g acetylene 8–10 per cent). On each side of this zone are mixtures which are inflammable, but with less violence, until outside the limits the mixtures are not inflammable at ordinary temperature and pressure. It will be noticed that the proportions vary considerably with different gases. They also vary with the same gas according to temperature and pressure, and the nature and position of the source of ignition.

PERCENTAGE OF GAS OR VAPOUR IN AIR TO CONSTITUTE AN INFLAMMABLE MIXTURE (i e IGNITION ZONE)

	Lower limit	*Upper limit*
Acetylene	3	82
Hydrogen	7	73
Coal gas	8	23
Petrol vapour	1 5	6
Carbon monoxide	13	75
Carbon disulphide	[illegible]	50
Ether (ethyl ether)	2	42
Acetone	3	13

PRECAUTIONS

Where inflammable gases or vapours are liable to be present two precautions should be observed to reduce the danger to a minimum.

1. **Ample and suitable ventilation** should be provided to remove the gases, and prevent them forming an inflammable or explosive mixture with air—mechanical ventilation is almost always necessary Many gases and vapours used in industry are heavier than air, and ventilation should, therefore, in these cases be at floor level, but where the gas is lighter than air the ventilation should be at ceiling or roof level. Hydrogen, coal gas, producer gas, acetylene, ethylene, and carbon monoxide are examples of gases lighter than air, while the vapours of acetone, ether, benzol, petrol, carbon disulphide are heavier than air.

Where vapours are produced at one point, e.g. at a rubber spreading table, a hood can be provided connected with metal trunking through which the vapours are drawn, often to a *solvent recovery plant*. Such a plant may contain activated charcoal, which absorbs the vapours, they are subsequently recovered as liquids by steaming them out of the carbon and condensing them. The plant should, of course, be in a detached building and precautions taken against explosion.

2. **Prevention of ignition** of any inflammable mixture formed in spite of ventilation, by removal of any possible source of ignition, e g. naked lights or flames, stoves or ovens, electric, static, or frictional sparks, glowing tobacco, overheated bearings. Precautions for lighting and heating are set out on page 68 and for electric motors on page 116.

Damage from explosions can often be limited by the provision of relief panels. Buildings where very hazardous processes are carried on can advantageously be of light construction as the less an explosion is confined the less is its intensity.

INFLAMMABLE LIQUIDS

Wherever inflammable liquids are used or stored it must be assumed that inflammable vapours are likely to be present and

the appropriate precautions taken. As the less the liquids are exposed to the air the less they will be vaporized they should be kept in sealed containers when not in actual use. Sometimes it is possible to use a non-inflammable liquid instead of an inflammable one, or at any rate to use one which is less inflammable, e g. white spirit instead of benzene for dry cleaning.

Fatal accidents and explosions have often occurred during the inspection or repair of vessels which have contained petrol or other inflammable liquids Such vessels are dangerous until every vestige of vapour and sludge has been removed and as little as $\frac{1}{5}$th of a cubic inch of petrol in the form of a film or sludge on the inside of a petrol tank of 1 cubic foot capacity is sufficient to produce an explosive mixture which only requires a spark or other form of ignition to explode It can be appreciated, therefore, why the soldering or brazing of joints of "empty" tanks or their inspection by naked lights or even electric inspection lamps (which are liable to spark at contacts or provide other means of ignition) frequently causes explosions Tanks should be thoroughly cleared of vapour by immersion in boiling water or steaming for some hours before inspection or repair Another frequent cause of accidents is that of persons with oil-saturated clothing approaching a fire or other source of ignition Some of the more commonly found inflammable liquids are—

Alcohol is chemically the name of a class of compounds, but is often applied to one member—ethyl alcohol Absolute alcohol (i e. 100 per cent pure) has a flash point of about 50° F , but it is generally mixed with varying proportions of water, the effect of which is to raise the flash point, rendering it less inflammable, e g a 50 per cent mixture with water has a flash point of 75° F It is used in the manufacture of alcoholic beverages, for many other purposes its place is taken by methylated spirits—a mixture of ethyl alcohol and methyl alcohol, or wood spirit, with the addition of a small quantity of mineral oil to make it unpalatable. Methyl alcohol has a rather lower flash point than ethyl alcohol. Alcohols are largely used in the manufacture of dyes, varnishes, as fuel, and as solvents for essences, cellulose nitrate, resins, and other substances.

Carbon disulphide (bisulphide of carbon), a colourless, or pale yellow, liquid, is very volatile and inflammable having flash point about − 22° F. and ignition point about 300° F., thus it can be ignited by such sources of heat as a frictional spark or a hot (below red heat) shaft. It should be stored in cool places in airtight drums, and must not be stored in sunlight owing to the risk of the containers bursting and the released vapour igniting It is heavier than water, with which it will not mix, and a layer

of water on its surface will prevent evaporation Used as a rubber solvent, in boot factories, in artificial silk works, and as a fumigant, it is one of the most hazardous liquids used in industry.

Ether (ethyl ether). Colourless liquid, very volatile and highly inflammable. Mixtures of its vapour and air are explosive over a very wide range. Should be stored similarly to carbon disulphide. Used as an anaesthetic and as a solvent.

Mineral and rock oils (hydrocarbons) include petroleum, which is obtained from oil reservoirs beneath the earth's surface, and oils obtained by distillation from bituminous coal or shale.

Spirits (including petrol, naphtha, benzene) have varying flash points, but mostly very much below 73° F., which is the arbitrary temperature fixed by the Petroleum Acts, below which the products are known as petroleum spirit, and their use controlled by the Acts At ordinary temperatures they give off inflammable vapours, of which a small proportion in air is sufficient to form an explosive mixture The vapours, which are easily ignited, are heavier than air, and may migrate a considerable distance, or, in the absence of a draught, may accumulate on the floor.

No petrol or other spirit should be stored in buildings unless in sealed cans, kept in special fire-resisting compartments, ventilated to the open air at ground level, and having well-fitting iron doors A deep sill should be provided to form a pit to retain the liquid in the event of leakage Where petrol-driven vehicles are garaged the aggregate quantity of petrol in their tanks may be considerable, tanks should not be filled inside the garage.

The best method of storing petrol is in underground tanks sunk in the earth, two or three feet below ground level, and concreted over. The tank is filled by hose connection from a tank wagon and spirit is withdrawn by means of a pump situated above the tank. The pump, filling connections, and vent pipe should be in the open air. Petrol is often used in garages for cleaning purposes—a dangerous practice—and kerosene is preferable Often tailors, etc , keep a small quantity of petrol in a bottle for removing grease spots, but this is not a practice to be encouraged, and, if a non-inflammable solvent, e g carbon tetrachloride, is not used the spirit should be kept in a metal receptacle with screw stopper and the quantity limited to, say, half a pint. The use of petrol in domestic dry-cleaning and other operations has caused many fires and fatalities. It should never be used indoors.

Paraffin or *kerosene* has flash points varying from 73° F. (below this the liquid is classed as petroleum spirit) to about 120° F. It does not ignite so easily as petrol and does not give off inflammable vapours at ordinary temperatures in this country.

When ignited it burns fiercely, and unless in very small quantities should not be stored in buildings. A usual and satisfactory arrangement for storage at grocers' and domestic stores is to have a tank situated in the open yard, from which the oil is pumped by hand to a tap in the shop at a higher level than the top of the tank. Customers' receptacles are filled at this tap, beneath which is a sink with a waste pipe, through which surplus oil flows back to the outside tank by gravity, thus ensuring that there is no oil left in the pipe or in the building. Care must be taken that the sink is large enough to avoid the spilling of oil on to the wooden floor, which, if impregnated with oil, would be very inflammable.

Storage inside buildings is unsatisfactory, as is the arrangement, often found, by which oil from an outside tank flows to a tap in the building by gravity, for in the event of the pipe-line fracturing, or the tap being left dripping, the whole contents of the tank could flow into the shop. Where small quantities of oil are kept in a building, arrangements should be made to avoid floors being soaked with drips, e g. by providing a metal tray containing sand, or by using a "safety" cabinet from which the oil is drawn by hand pump on top of the cabinet, any drips returning to the tank.

Lubricating oils of varying grades and heavy oils used as fuel oil or for use in heavy oil engines. The flash point of these oils is higher, say 150° to 600° F., and there is less risk of their ignition. When heated they will burn freely, and care is required in their use and storage See Oil Fuel, page 118

Motor garages, and other places where large quantities of lubricating oils are required, are now often supplied with underground tanks, having draw-off pumps after the fashion of petrol pumps.

Extinguishment of Oil Fires

Water, ordinarily applied from hoses or buckets, is useless in connection with the extinguishment of oil or spirit fires, in fact its tendency is to scatter the liquid and spread the fire Carbon dioxide, carbon tetrachloride, and steam may all be used in appropriate circumstances, but the methods usually adopted are—

Foam Either chemical or mechanical foam can be applied to the fire, forming a blanket, which floats on the surface of the burning liquid, excluding air and thus extinguishing the fire. In the case of large tanks it is desirable that fixed piping be provided in order that foam can be applied with as little delay as possible Doubts have been expressed whether foam is efficacious on alcohols owing to their propensity for absorbing water and thus perhaps causing the foam bubbles to break down. It has been demonstrated, however, that some types of foam are satisfactory, much depends on the rate of application.

Water spray nozzles. Although water must not be applied by hose streams, it can advantageously be utilized by the employment of spray nozzles Fixed systems, of which the "Mulsifyre" and "Oilfyre" are examples, are adaptations of the principle of automatic sprinkler protection, but fixed piping systems can also be manually operated. Spray nozzles can also be used with hose lines. In the form of a fine spray or mist water cools the burning surface of the oil, excludes air, and in the case of some oils forms a temporary emulsion on the surface of the liquid. Care must be exercised in the application of water even in this form as if the bulk of the inflammable liquid is very hot it may foam over and spread the fire.

Spray nozzles are more effective on liquids not miscible with water than on those which will mix with water. The latter can be extinguished by adding sufficient water, e.g. a mixture of less than 15 per cent of alcohol with water will not burn, but large quantities of water will in many cases be required and the burning liquid may overflow before sufficient water has been added.

Of the solvents mentioned on page 60 methyl alcohol, acetone and methylated spirits are miscible with water; ethyl acetate is slightly miscible, but amyl acetate, butyl acetate, and benzene will not mix with water. Only methylated spirit of the liquids mentioned on page 48 is miscible with water. The specific gravity of the liquids in both lists is less than that of water, on which therefore they will float; the one exception is carbon disulphide on the surface of which water, if gently applied, will float and extinguish the fire.

CHAPTER IX

DUST EXPLOSIONS

How dust explosions arise—Classification of dusts—Precautions

DUST lying in heaps on a floor, though objectionable from an aesthetic point of view, is not generally dangerous If, however, the dust of any carbonaceous, or other easily combustible material, be held in suspension in the air in the form of a cloud it becomes hazardous, for it is then in intimate contact with the oxygen essential for combustion, indeed the particles absorb oxygen like a sponge. Thus, the finer the state of division the more dangerous is the dust, owing to the much greater surface exposed to the air and the longer the period during which it will remain in suspension, contact with a suitable source of heat will result in an explosion.

A mixture of dust and air is analogous to a mixture of gas and air and, as with gas explosions, the maximum effect is obtained when the proportions of dust and air are such that there is just sufficient oxygen to ensure complete combustion. As the proportions depart from these, whether there be too much or too little dust suspended in the air, so will an explosion be of less intensity, until outside certain limits the risk of explosion ceases

The source of ignition usually must be larger than that necessary for gas-air mixtures, prolonged application of a large source of heat of moderately high temperature, e g a flame, is more likely to cause ignition than, say, a spark of much higher temperature, but of short duration

The dusts most liable to explosion are carbonaceous dusts and the explosion is due firstly to the great, practically instantaneous, increase in pressure, resulting from the heat liberated by the combustion of the dust particles and, secondly, from the copious gaseous products of their combustion Dust explosions are frequently of greater intensity than gas explosions, by reason of the larger amount of combustible matter contained in a given volume, and the finer the dust the more rapid is the explosion

Frequently, a dust explosion happens in two parts—the first comprising ignition of the air-dust mixture, resulting in an explosion which, in itself not very violent, is sufficient to agitate dust lying on floors, ledges, etc , to form another dust cloud, which, ignited by the flame from the first explosion, produces the second —usually of greater intensity. Dust explosions have occurred notably in corn mills, but they have also been caused by dust

from sugar, cork, coal, rubber, rags, sulphur, magnesium, aluminium, pitch, wood, and other substances

As a result of tests conducted by Prof. R. V. Wheeler and the Home Office Factory Department, a large number of dusts have been classified according to their hazard Class I comprises dusts which ignite and propagate flame readily, the source of heat required for ignition being comparatively small, such, for example, as a lighted match This class includes sugar, starch, cocoa, rice meal, cork, soya bean, wood flour, malt, grain, cellulose acetate, maize, liquorice root, tea, compound cake, flour, cornflour, chicory, briquette, pitch, ebonite, erinoid, ground cotton, spent hops, cascara sagrada, and other substances. Class II are dusts which are readily ignited, but which for the propagation of flame require a source of heat of large size and high temperature, such as an electric arc, or of long duration, such as the flame of a Bunsen burner Class III are dusts which do not appear to be capable of propagating flame under any conditions likely to occur in a factory: (*a*) because they do not readily form a cloud in air, (*b*) because they are contaminated with a large quantity of incombustible material, or (*c*) because the material of which they are comprised does not burn rapidly enough or produces inert gas.

PRECAUTIONS

The precautions which should be taken to avoid dust explosions include those against the formation of dust clouds and those against ignition, as well as measures to limit the damage caused by an explosion.

Formation of dust clouds. Machines, trunks, and other points where dust is likely to arise should be so enclosed or arranged as to prevent the escape of dust. Dusty material should not be allowed to fall from spouts, but chutes should be provided to deliver the material gently so that a dust cloud is not formed At points where dust is evolved in dangerous quantities exhaust draught should be provided.

Dust should not be allowed to collect on ledges, floors, or elsewhere, as such accumulations might be dislodged by a draught; or a small explosion, itself causing little damage, might dislodge sufficient dust to form dust clouds, resulting in a more serious explosion Vacuum plant should be employed to remove such dust to prevent its accumulation

Ignition of dust clouds. No gas burners, open fires, stoves, electric luminous radiators, or other naked lights should be used, and gas and oil engines, boilers and gas producers should not be installed in parts of premises adjacent to portions in which inflammable dusts are likely.

Magnetic separators (which are electric magnets so placed that material fed into a machine passes over them and any iron or steel is held back by the magnets) should be fitted to all grinding machines in order to prevent mechanical sparking. Traps should be provided for collecting stones and other foreign matter.

All electric lamps should be enclosed in stout, dust-tight glass globes, for, in the event of breakage of the lamp, dust clouds might be ignited at the still glowing filament. Moreover, dust which settled on the lamp might be ignited even without breakage by the heat of the lamp.

The possibility of arcs, due to short circuits or other causes, should be reduced by enclosing all wiring in earthed continuous screwed metal conduits. Where a flexible lead is essential tough rubber-covered cable should be used and the lamp and wall fittings should be of the certified flameproof type. Switches, starters, fuses, etc, should be remotely placed in dust-free situations and motors should be of the flameproof type or pipe-ventilated to the open air

Static electricity is likely to be generated, but the likelihood of spark discharges can be minimized by suitably earthing machines, pulleys, etc., or, better, where the nature of the material being used permits, by humidifying the air, as this is not only a safeguard against static discharges, but reduces the inflammability of the dust

Where, as for example in coal mines, sufficient incombustible dust, e.g. stone dust, can be added to a material an explosion may be prevented and, in some instances, it may be possible to utilize inert gas in a similar manner.

Limiting explosion damage. The more confined an explosion, the greater is its intensity. By the provision of light relief panels in grinding machines, elevators, etc.; the expanding gases are enabled to escape more easily. An explosion in a machine can often be prevented from passing to other plant fed by it by interposing a worm conveyor choke tube or a rotary valve. As far as possible grinding machines should be installed in separate fire-resisting rooms having adequate relief panels.

Fire extinguishers. Ample portable chemical extinguishers should be provided. Fires following an explosion may be limited by the installation of sprinklers.

Specially hazardous materials. The grinding of cork, aluminium, magnesium and dyestuffs is especially hazardous and special precautions are necessary. Water or chemical extinguishers must not be used where metallic dusts are ground—powdered asbestos, asbestos graphite, powdered talc or dry sand should be applied gently so as not to disturb the dust.

CHAPTER X

CELLULOID. PAINT SPRAYING

CELLULOSE nitrate—Celluloid Cinematograph films—Cellulose solutions—Cellulose paint spraying—Precautions—Spraying other solutions

CELLULOSE is the chief component of all vegetable tissues, in which it exists as cells or fibres. Cotton-wool is almost pure cellulose and, for this reason, is the form most used in manufacturing cellulose products.

By treating purified cotton-wool with nitric and sulphuric acids, nitro-cellulose is produced, the characteristics of which vary according to the proportion of nitrogen in it. Gun-cotton, which contains 12·3 per cent or more, is both combustible and explosive, but the more important product commercially is "pyroxylin," a cellulose nitrate (or nitro-cellulose) in which the nitration has not been carried so far as in gun-cotton, i e. its proportion of nitrogen is less. Although not explosive, it is so highly inflammable that its combustion may, in favourable circumstances, almost appear to be an explosion, and it can continue to burn in the absence of air. It is soluble in alcohol and some other solvents, and is used in the manufacture of celluloid, photographic and cinematograph films, and cellulose paints and varnishes

CELLULOID

Celluloid is a mixture of cellulose nitrate (pyroxylin) and camphor dissolved in ether and alcohol or other solvents. The solvent is dried out, leaving celluloid, a tough, hard material, which is too well known to need description, and which is used in the manufacture of some toys, imitation tortoiseshell, cinema film, fancy articles, knife-handles, etc. It is highly inflammable, is easily ignited, and burns rapidly and fiercely. If heated to a temperature of 250° to 300° F without the application of flame (as might happen if celluloid were stored against steam or even high-pressure hot-water pipes) it decomposes, giving off an inflammable and poisonous vapour. Should this vapour be mixed with the correct proportion of air and ignited, an explosion would result

Celluloid articles have been known to ignite due to their being in contact with incandescent electric-light bulbs, carelessness in soldering tins containing celluloid, and by friction as in cutting with a saw (this should only be done under water) Owing to its large percentage of oxygen it will continue to burn in the absence of air, and for this reason it is practically impossible to extinguish

fires in large quantities of celluloid Copious quantities of water should be applied for cooling purposes.

Cinematograph film is thin, flimsy, and especially inflammable Film stores, or "vaults" as they are termed, should be of fire-resisting construction, well ventilated, strictly limited as to size, and each spool of film should be contained in a separate metal container. A space should be allowed between containers, in order to prevent the heat of a fire in one from being conducted to other containers Where sprinklers are installed in film vaults it is not so much with the idea of extinguishing a fire as of keeping other containers cool in the event of fire in one of them.

Wherever celluloid is worked or used the amount in the workshop should be restricted to a minimum by bringing in, at a time, only sufficient for immediate needs, and removing as soon as possible All scraps and cuttings should be collected in self-closing metal bins and removed frequently Where celluloid articles are stored they should be kept in closed metal cases, and if there are large quantities it is highly desirable that they be kept in compartments of fire-resisting construction, similar to film vaults

"Non-inflammable," "slow-burning," or "safety" celluloid is usually made from cellulose acetate (i e the cellulose is treated with acetic acid instead of nitric acid) and burns in the manner of paper rather than the fierce and rapid way of celluloid From consideration of cost, and by reason of its lacking some of the properties of celluloid, this substitute does not replace celluloid in the manufacture of cinematograph film, but it is largely used for X-ray and "baby" ciné films, also for transparent wrapping papers, e g. cellophane, etc. Many articles previously moulded from celluloid are now moulded in non-inflammable plastics, e g. erinoid, bakelite, etc.

CELLULOSE SOLUTIONS (PAINTS, LACQUERS, VARNISHES, ETC)

The simplest form of cellulose solution would be scrap celluloid dissolved in, say, acetone, and if such a solution were applied to a surface the solvent would evaporate, leaving a thin coating or film of celluloid on the surface This film, owing to its thinness and close contact with a surface exercising a cooling effect, would present little hazard, but during the evaporation of the acetone an inflammable vapour would be given off

Although, in some paints, scrap celluloid and stripped cinematograph film is indeed used, the bulk of cellulose solutions have, as a basis, cellulose nitrate dissolved in a suitable solvent Amyl acetate (flash point 90° F.), butyl acetate (75° F.) and ethyl acetate (23° F.) are generally used but, as they are expensive, they are diluted with acetone (0° F), methylated spirit

(35° F.), benzene (15° F), methyl alcohol (30° F), and other solvents—all highly inflammable Such a solution would, on drying, leave a somewhat brittle film, and flexibility is given by adding "plasticizers" in the form of castor-oil, gums, and resins The solutions are usually supplied thicker than required for use and the user thins the solutions to the desired consistency by the use of "thinners," which, too, are highly inflammable.

For many years such solutions have been used in the manufacture of waterproof cloths and imitation leathers, being applied to textile fabrics in more or less airtight machines, but of recent years cellulose painting has become popular in many trades, notably the motor industry.

Cellulose Paint Spraying

Articles are sometimes dipped in baths of cellulose paint or the paint may be applied by brush as in the "doping" of fabric aircraft wing coverings, but the usual method of application is by spraying The advantage of this method is that it is very much quicker both in application and drying than ordinary brush-painting, and, in skilled hands, gives a very good appearance to the work

The spraying is done by means of apparatus consisting of a receptacle in which paint is placed, and from which it flows in a thin stream to a "pistol," where it is met by a stream of compressed air, fed to the pistol through a flexible tube, from an air compressor. The air pressure breaks up the paint stream to a fine spray, which is projected on to the article to be painted, though a quantity is inadvertently sprayed on the surroundings, such as the bench or floor on which the article is placed These deposits, being essentially cellulose nitrate, are exceedingly inflammable, and it is necessary that they are not allowed to accumulate A fibre or non-ferrous scraper should be used to remove them, as, if an iron instrument were used, a frictional spark might ignite either the scrapings or any dust from them in the surrounding air. They are liable to spontaneous combustion, especially if allowed to accumulate on a heated surface, e.g. steam pipes, or if cellulose paints are sprayed alternately with oil paints

When cellulose paints dry they do not, as in the case of oil paints, slowly oxidize, but the solvents simply evaporate, leaving behind the solid constituents as a film The vapours thus given off are both harmful to health and form explosive mixtures with air. These vapours may be considered in the same way as any other inflammable vapour, and the precautions to be observed fall into two groups—ventilation to remove the vapours as quickly

as they are formed, and exclusion of any possible source of ignition. Small articles are sprayed in cabinets or booths enclosed on all sides except the front, where the operator stands, and ventilated at the back by a fan, driven either by belt from a motor or other source of power outside the booth, or direct by a flameproof or pipe-ventilated electric motor Generally, several of these booths are erected against an external wall in order that the fan may exhaust direct to the open air, thus obviating ducts and trunking in which deposits could accumulate. It is desirable that the group of booths be separated from the remainder of the works by a wall or partition to prevent vapours migrating. Large articles, such as motor-cars, require to be painted in separate rooms, and no work other than spraying should be allowed in these

PRECAUTIONS

Situation All handling of cellulose solutions, whether mixing, spraying, or other process, should take place only in a compartment used for no other purpose, separated from the remainder of the premises by walls or partitions, preferably of incombustible materials, so constructed as to prevent vapours drifting to other departments. Unless the partitions extend to the ceiling or roof a false ceiling should be provided. Inlets for air to replace that exhausted by the fans should be well above floor level in order that the vapours, which are heavier than air, shall not drift out through them

Ventilation. Artificial exhaust ventilation is always necessary, the heaviness of the vapours precluding reliance being placed on natural ventilation. Whenever possible the fans should discharge direct to the open air, but where this cannot be arranged the ducts should be of large diameter, constructed of metal, as short as practicable and without sharp bends in order to avoid accumulations of residues Sometimes water sprays are provided through which the exhaust vapours pass and by which a large proportion of the residue is trapped

The exhaust fans, which should be installed near floor level, should be capable of changing the air in the compartment thirty times per hour, and should be run for some minutes after work has ceased.

Deposits or residues are readily inflammable and may be ignited by a frictional spark They are also liable to spontaneous combustion Booths, ducts and elsewhere where deposits can accumulate should be cleaned frequently, at least weekly, with fibre or non-ferrous scrapers.

Cleaning rags, etc., should be kept in metal receptacles and removed frequently.

Lighting. The only permissible form of artificial lighting is incandescent electricity, the lamps being enclosed in stout glass globes. Where electricity is not available gas or other lighting may be installed externally, the light entering the compartment through windows or skylights of fixed plate glass.

Heating. The best methods of artificial heating are low pressure hot water pipes or steam-warmed air, the heating apparatus in each case being outside the compartment and as far away as practicable. When steam pipes or electric radiators are used they must be adequately protected to prevent deposits on them, as at temperatures over 212° F. the deposits are liable to decompose and ignite. Ordinary glowing element electric fires, gas fires or radiators or any other forms of heating are not permissible Smoking should be prohibited in or near the room

Electrical equipment should, as far as possible, be excluded from the compartment, and all necessary apparatus should conform to the appropriate specification of the British Standards Institution. Wiring should be in screwed metal conduit screwed at the ends into the cases or fittings, etc , so as to enclose completely the whole length of the wiring Motors, switches, heaters, and all other apparatus should be of the flameproof type, and no portable appliances or flexible wiring used.

Storage. The stocks of paint, thinners, etc., should be kept in a detached store of fire-resisting construction provided with a deep sill in order that any leakage shall be retained. Only sufficient for one day's use should be taken into the workshop, and while there should be kept in a metal cupboard when not in actual use. Empty drums and tins should be removed to the storeroom

Extinguishment The provision of ample fire-extinguishing appliances is very desirable Some doubt has been cast on the efficiency of foam extinguishers, as cellulose solvents and thinners tend to break down the foam bubbles It has, however, been demonstrated that some types of foam are satisfactory and that much depends on the rate of application. It is probable that this type of extinguisher is generally the most suitable.

Spraying of Other Than Nitro-cellulose Solutions

Although nitro-cellulose solutions are those most commonly used, almost any liquid or semi-liquid can be sprayed Paints embodying synthetic resins (known as "synthetic paints") are widely regarded as much safer than cellulose paints It is true that deposits from these paints are less hazardous than cellulose deposits, but the solvents used are similar, and inflammable vapours are freely given off, as is also the case with aluminium paint.

In the building and decorating trades ordinary oil paints, varnishes, and whitewash are similarly applied. In the furniture and leather trades, french polish and various water or spirit stains are frequently sprayed, and in many other trades spraying finds application The risk varies according to the properties of the materials and the solvents employed, bearing in mind that, if combustible in their usual condition, they will be more easily combustible when mixed with air in the form of a spray Any of those usually employed is less hazardous than a nitro-cellulose solution, and the precautions may be relaxed to a greater or lesser extent according to the hazard of the constituents, particularly of the solvents used Where the degree of hazard is not clear, information can often be obtained from the manufacturers as to the materials utilized in the preparation.

CHAPTER XI

LIGHTING AND HEATING—GENERAL

FLAME—FIRE hazards naked flames, effect of heat on combustible materials, lighting up, inflammable gases, vapours, and dusts—Comparison of methods

IN any classification of the causes of fire it is found that a substantial proportion is attributed to forms of lighting and heating That "heating" figures prominently should not cause any surprise, as a fire in, say, a grate is of the same nature as a fire which demands the attention of the Fire Service; the only difference, although this is an important one, being that the first is confined to its proper place, while the second is, as it were, unfettered. Light in itself is not a hazard, but as in all forms of lighting, heat is occasioned—indeed, the light is dependent on heat being generated—lighting can well be considered, from the point of view of fire hazard, as a form of heating.

From the humblest cottage to the largest factory the risks of fire arising from lighting and heating systems exist, and whatever the method employed its hazards should be considered under two headings: (1) The hazard inherent in the method, which, of course, cannot be entirely eliminated, although it can be minimized, (2) the particular risks due to the situation where the apparatus is installed, including the conditions under which it is used. As an example, lighting by coal gas usually presents quite a small hazard, but if a gas burner is installed in a cellulose spraying booth, the likelihood of a fire occurring is very great. A fire-heated stove may be non-hazardous standing on a concrete floor in an engineer's workshop, but it is a real hazard on a wooden floor in a saw mill

FLAME

In all forms of lighting other than by electricity a flame is utilized, either as a luminous flame by itself, e.g. a candle, or in the form of a non-luminous flame employed to heat a mantle to incandescence Flame may be said to be burning gas, e g. when coal gas burns a chemical action takes place in which the combination of hydrogen, oxygen, and carbon generates heat. If this combination, or combustion, is imperfect, minute particles of carbon in the centre of the flame, which are not in contact with air and are unable to enter into combination, become heated to incandescence by the heat of the reaction of the oxygen and hydrogen, and thus a luminous flame is produced. If, however,

sufficient air is mixed with the coal gas before it enters the burner, these carbon particles are in contact with oxygen and are able to enter into combination with it. This enables more perfect combustion to take place, and although light is not emitted, more heat is generated It may be said then that a non-luminous flame is hotter than a luminous one, and such a flame is employed to heat to incandescence a mantle which, being impregnated with substances which emit a brighter light than carbon particles, gives a stronger light than a luminous flame by itself

It is well to remember that all ordinary flames are burning gas Although liquids and solids appear to produce flames, when they burn, the flame is in fact the burning of the vapours and gases to which heat has converted the liquids and solids This can be seen clearly by close examination of the flame of a candle or a lighted match.

Fire Hazards

There are a number of hazards common to most forms of lighting and heating

Naked flames. Whenever there is an unprotected flame, the possibility exists of combustible material coming into contact with it Many fires are caused by curtains blowing into the flame of a gas burner or through inflammable materials being hung close to a burner as is sometimes done in drapers' shops, etc

Some protection can be afforded by providing wire guards or globes, but these are unsightly and, as they are liable to harbour dust or fluff which may itself be ignited and fall on combustible materials, the cure may be worse than the disease Glass lanterns entirely enclosing the burners are an excellent protection, but generally ordinary stout glass globes are reasonably satisfactory Should shades of combustible material such as silk be used, they should be fixed rigidly in such a manner that there is no possibility of the shade becoming ignited When lights are movable, e.g swing brackets and portable lamps, the risk is greater, as not only can inflammable material be moved into contact with the flame, but the flame can be moved into contact with inflammable material

Effect of heat on combustible materials. The fact that inflammable material such as textile fabrics coming into contact with naked flames is likely to start a fire, is generally understood, but it is not so commonly appreciated that heat alone (without any flame) will ignite such articles Clothes left airing in front of and too near to an open coal or gas fire often ignite because sparks are thrown on to them or they fall into the fire, but they are often ignited merely by reason of heat given out by the

fire, which first scorches the clothes and then causes them to ignite Electric lamps have been known to become hot enough to ignite combustible matter in contact with them

As wood is used to such a large extent in the internal construction and furnishing of buildings it is important that the effect of heat on wood is understood Up to about 212° F practically only the moisture which is contained in the pores of the wood is driven out, but at slightly higher temperatures minor changes occur At about 300° F hydro-carbon gases are expelled, at about 450° F the wood commences to change into a brown form of charcoal, and at higher temperatures black charcoal is produced In a fire, the combustion first takes the form of flaming combustion of the gases, and subsequently the combustion of the non-volatile charcoal-like remains, which glow and also produce the combustible gas, carbon monoxide

The "brown carbon" which is formed at 450–500° F has the property of igniting very easily, even a current of warm air, as from a lamp, will cause it to ignite

It is a peculiarity that similar conditions are produced at very much lower temperatures, provided the heating is sufficiently prolonged. Even temperatures as low as 300° F are sufficient to render the wood ready to combine with the oxygen of the air, and the tendency is enhanced when the heating is not only prolonged but intermittent Such conditions are found, for example, where a wood ceiling is over a baker's oven or woodwork is adjacent to a stove or furnace a blast of hot air impinging on the charred wood will cause it to take fire.

The most effective precaution is to arrange that no wood is sufficiently near to any form of heat to be endangered in this manner The distance which should be observed depends on the nature of the heating or lighting apparatus involved and also whether the wood is over, under, or at the side of the source of heat Gas burners for lighting should be provided with a metal shield fixed between the burner and the ceiling, and not within 12 inches of either, in order to prevent the heat given off from rising directly to the ceiling, where coal or coke stoves stand over a wood floor, a base of stone, brickwork, or concrete at least 3 in thick should be provided (a sheet of metal or asbestos cement sheeting is useless, as it does not prevent transmission of heat to the floor), metal smoke pipes should not be fixed nearer than 9 in to combustible materials. Where a fire-heated stove is situated within, say, 24 in horizontally from any woodwork, e.g a matchboard partition, some protection can be given to the woodwork by fixing metal or absestos cement sheeting between the stove and the woodwork The sheeting must not be in contact

with the wood, but can be satisfactorily secured to it by long screws having distance pieces so that the metal is, say, 2 in. from the wood, thus permitting a current of air, itself a good heat insulator, to circulate between the sheet and the woodwork.

Lighting up. Most lighting and heating devices, with the exception of electric ones, require to be lit by means of a spark or flame If matches are used, the still glowing match may be carelessly thrown down and ignite some inflammable material, or, if a piece of paper or a wax or wooden spill is used to transfer a flame from one point to another, it is possible for burning fragments to fall from it It is not unknown for paper so used to burn the fingers of the "lighter up" who promptly drops the still flaming torch. But note· smokers, too, use matches and spills. Where in a factory a large number of gas burners has to be lit it is very desirable that they are all lit by one man who can be provided with either a spirit torch of a type specially made for such purpose or, better still, with an electric lighter.

Inflammable gases, vapours, and dusts. In places where inflammable gases, vapours, or dusts are likely to be present it is essential that the methods of lighting and heating adopted are not such as would provide a source of ignition.

The only permissible form of lighting in such a building is by incandescent electric lamps, which should be enclosed in stout glass globes, otherwise in the event of breakage of the lamp the still glowing filament would be exposed All wiring should be completely enclosed in earthed continuous metal conduit screwed at both ends into the cases of fittings, etc Inspection lamps with trailing leads and other portable apparatus should not be used. Switches and fuses should be remotely placed in vapour-free situations Gas lighting cannot be permitted—if electricity is not available gas or other lights should be installed externally, the light entering the building or room through windows of fixed plate glass.

The only suitable methods of heating are low-pressure hot-water pipes or radiators, the boiler being outside the building, electric heaters of the immersion type or of totally enclosed low-temperature types, or, where heavy continuous concentrations of vapour are not likely, e g in motor garages, gas radiators of the miner's safety lamp type. Ordinary gas or electric fires, open fires, pipe stoves, and any other appliance which might provide a source of ignition to the gas, vapour or dust should not be permitted, nor should portable apparatus be used.

Comparison of lighting and heating methods. It is sometimes assumed that lighting by electricity is less hazardous than lighting by any other method. Where inflammable and explosive vapours,

gases, or dusts are liable to be present or where inflammable materials are handled this is true, but in general the fire hazards of electricity cannot be considered as less than those of coal gas One point which can be advanced in favour of gas lighting is that any leak, whether due to poor workmanship or wear, is easily detected by the smell, while a leakage of electricity may continue unnoticed a considerable time; on the other hand it is a very good point in favour of electricity that there are no naked lights.

Insurance companies regard coal gas and incandescent electricity as equally acceptable in situations other than those where especially flimsy or inflammable materials or inflammable gases, vapours or dusts are likely to be present, but often impose additional rates for other methods of lighting. Similarly, heating by ordinary coal fires, gas and electric fires and radiators, low-pressure hot-water or steam pipes is regarded as normal, while the use of oil stoves, pipe stoves, high-pressure hot-water or steam pipes and fire-heated hot-air plants is discouraged It should be mentioned that portable apparatus of any kind, especially coke buckets (or cokels), is regarded with disfavour.

CHAPTER XII

LIGHTING AND HEATING BY OILS, SPIRITS, AND SOLID FUELS

OIL lamps burning oil at a wick—Mineral oil vaporizing lamps—Petrol vaporizing lamps—Petrolite lamps—Naphtha flares—Oil stoves—Fireplaces construction, hearths, chimneys, fenders—Pipe stoves· base, fender, smoke pipes—Portable coke fires

OIL LAMPS

THERE are now relatively few places where gas or electricity are not available, but a surprisingly large number of persons still rely on oil appliances or even use candles, which are responsible for many fires. Candles should only be used when fixed in candlesticks with large bases which cannot easily be overturned, and should be placed where it is not possible for combustible matter to come into contact with them

A number of different types of lamps burn oil, but for the consideration of their fire hazards they can be divided into two classes—

1· Those in which oil is burned at a wick, either with or without a mantle, known generally as oil lamps.

2 Those without wicks, in which a mantle is heated to incandescence by oil vaporized at the burner and known as mineral oil vaporizing lamps

In addition to the hazards mentioned below all lamps are subject to those of lighting up, naked flames, proximity of combustible materials, the presence of inflammable gases, vapours and dusts, and of portability. The last named is particularly important as, not only may combustible materials be ignited in the event of the lamp being overturned or dropped, but the oil is likely to escape from the reservoir and "flare up." The problem of filling arises: this should never be done when the lamp is alight or when it is near to another light, and care should be taken to avoid overfilling or spilling oil over the lamp The best arrangement is for lamps to be regularly cleaned and filled in a special place, preferably in an outbuilding, and over a metal tray to retain any spillage Oil should be stored in an outbuilding to prevent its assisting any fire which may occur in the main buildings.

1. Lamps burning oil at a wick. Animal and vegetable oils were burned in lamps as early as 3500 B C., and such oils are still used in a few types of lamp, e.g "watchmen's" lamps, which are often of the locked type, though watchmen are now usually provided with an electric battery lamp. They may also be used (although it is more common to-day to utilize mineral oil) in

portable hand lamps, sometimes known as duck lamps, in which a wick passes from a metal reservoir through a tube, at the end of which the wick is lighted The flame is unenclosed, gives a poor light and smokes, but the lamps are used in such places as brick works where no lighting system is installed, and sometimes by workmen when oiling machinery in dark places

For general lighting and heating purposes, vegetable and animal oils have been superseded by mineral oil owing to its volatility and the greater brilliance of its flame. The oil used is known as paraffin or kerosene, and has a flash point over 73° F., as the law prohibits the sale as lamp oil of any oil flashing below this temperature Before this regulation was made many explosions had occurred in lamps due to the use of mineral oil of low flash point, and glass instead of metal reservoirs were often used in order that the heat from the burner should not be transmitted to the oil and vaporize it. It is safe to say that provided proper lamp oil is used in a well-constructed lamp, of which the bottom part has not become loose, and that the wick is not defective, the risk of explosion is remote. Glass reservoirs must be regarded with disfavour as being more liable to damage by accident than a metal reservoir

Lamps burning oil at a wick either give a luminous flame or, by the addition of air at the burner, give a less luminous but hotter flame utilized to heat a mantle to incandescence. The glass chimney which is usually provided in each type to provide a draught serves to some extent to keep inflammable materials away from the flame.

2. Mineral oil vaporizing lamps (pressure lamps). In these lamps a mantle is heated to incandescence by a non-luminous flame from a burner to which a mixture of air and oil vapour is supplied, the oil having been vaporized immediately before entering the burner They must not be confused with those oil lamps described above which have mantles but in which the oil is fed to the burner by a wick

In one type, a reservoir of oil (paraffin) is supplied with a small air pump by means of which an air pressure of 20-30 lb per sq in is produced in the reservoir. The oil is thus forced through a small nipple and turned to vapour in a vaporizing tube set over the burner Here it mixes with air and reaches the burner as a vapour-air mixture The lamp will, of course, function only when the vaporizing tube is heated When the lamp is in action the tube is heated by the burner itself, but on starting it must be warmed up by an auxiliary flame before oil is allowed to flow from the reservoir. This is generally achieved by igniting some methylated spirit in a tray fixed under the tube This introduces

a hazard additional to those attaching to ordinary oil lamps. Should the tube not be sufficiently heated before the oil is turned on, oil instead of vapour will emerge from the tube and possibly flood the lamp and ignite It is necessary to keep the various parts clean and the wire gauze near the mantle in good condition. As considerable heat is generated, such lamps should not be placed within 2 ft 6 in. of a non-fire resisting ceiling (and if within 5 ft. the ceiling should be protected with sheet asbestos ¼ in. thick and 5 ft in diameter), nor within 5 ft. of any combustible material. A metal heat deflecting shield must be fixed to the top of each lamp.

In the lamp just described the oil container forms part of the lamp, but another, less usual, arrangement is to have the *oil contained in a tank remote from the lamp or lamps being supplied.*

The oil tank should be outside the main building or in a fire-resisting compartment and fitted with a pressure gauge and a relief valve to prevent the pressure in the installation exceeding 100 lb per sq. in An alternative to air pressure in such installations is to provide pressure in the oil tank by carbon dioxide gas from cylinders

Petrol Vaporizing Lamps

These are very similar to mineral oil vaporizing lamps, both in operation and fire hazard, but even greater care is required owing to the volatility and lower flash point of petrol. A method sometimes adopted in connection with systems where the tank is remote from the lamp is to supply the petrol to the lamps by gravity instead of by air pressure. The tank should be placed outside the building and a stop valve fitted near the tank

Petrolite lamps burn petrol vapour at a burner which heats a mantle to incandescence The petrol container is fitted with an absorbent material, which holds the petrol as in a sponge, so that risk of leakage, even should the lamp be overturned, is obviated. No air pressure is needed and the lamp may be considered safer than the vaporizing lamps previously described.

Naphtha flares. This deplorable form of lighting, previously much used on open-air stalls, is now obsolete. The naphtha (or perhaps paraffin) was contained in a reservoir, from which it flowed by gravity through a tube to an open burner, where it vaporized and burnt freely, flaming drops often falling meanwhile

Oil Stoves

Oil stoves for heating may be divided into two classes similar to those under which oil lamps were considered, i.e. those employing wicks and those vaporizing oil without the use of a wick Paraffin is the oil used in each type and the hazards are similar

to those of lamps. Nearly all oil stoves are portable. They should stand in metal trays to catch any oil spillage, should be fixed to the floor whenever possible, and must be kept clean.

Oil stoves with wicks. These include the well-known "Beatrice" and "Valor" stoves, which have luminous flames and consequently do not give so great a heat as "blue flame" types, which, by having a burner so constructed that a greater proportion of air is taken up, give a non-luminous flame. Such stoves are frequently used for cooking in places where gas is not available, for warming offices and dwelling rooms, and for odd purposes such as boiling a kettle or heating glue

Oil stoves without wicks, of which the "Primus" is an outstanding example, consist of an oil reservoir with small air pump. The air pressure forces the oil through a tube or neck, where it is vaporized and passes through a nipple, mixing with air immediately under the burner. While alight the burner keeps the neck sufficiently warm to vaporize the oil, but for starting up methylated spirits is burned in a cup fixed to the neck

Some stoves similar to this type are designed to burn petrol Care must be taken not to attempt to use petrol in a stove intended for paraffin

Fireplaces

An open fire produces the most comfortable and cheerful form of warmth and also ensures a measure of ventilation The main types of open fires are those with metal bottoms to hold the fuel, set some inches above the hearth, and those known as "sunken" or "well" fires, where the fuel is burnt on, or in a well in, the fireclay base which actually rests on the hearth. When sunken fires are used the hearth gets much hotter than when there is an air space between the fire and the hearth

Construction. The danger to be apprehended from the constructional features of a fireplace lies in the possibility of joists or other woodwork being insufficiently protected from the heat of the fire. Owing to building by-laws, fireplaces in modern buildings are not a great danger, but in old buildings fires frequently occur because a beam which had been placed too near or under a fireplace ignites Such a beam may smoulder for a considerable time before it is detected; access of air will cause it to burst into flames.

Hearths should be 6 in thick, of stone or concrete, and extend 6 in beyond the fire opening on each side and 18 in. wide in front of the chimney breast In some old buildings the hearth rests on the wood joists which run under it to the wall. This practice is a frequent cause of fires which could have been obviated by

"trimming" the joists around the hearth, i.e the joists which would otherwise pass under the hearth are cut short of the hearth and the cut ends supported on a "trimmer," which is itself supported on the "trimming joists" which reach the wall on the outsides of the chimney breast The portion of the hearth known as the front hearth, which projects into the room, may be supported by a trimmer arch of brickwork, but by far the more usual method is to use a concrete slab resting on wood fillets nailed round the trimmer joists. The slab may be *precast* or may be cast *in situ* If the latter, any wood shuttering must be removed, but sometimes slates or asbestos are used as shuttering and these may safely be allowed to remain

Chimneys. The walls encasing the chimney and chimney breast of ordinary fireplaces must be at least 4 in thick, of brickwork or other incombustible material, and if the wall at the back of the fireplace is a party wall the thickness must be 8½ in up to a height of 12 in above the mantel If the chimney is used for trade purposes, e g for an hotel cooking range, the thickness of the brickwork must be greater, according to the circumstances, but should not be less than 8½ in Timber or woodwork must not be placed in any wall or chimney breast nearer than 12 in to the inside of any flue, nor within 2 in from the face of the brickwork of the flue if such brickwork is less than 8½ in thick, unless it is properly rendered Wood plugs must not be driven nearer than 6 in. to the inside of any flue or chimney opening

Fenders serve two purposes—to prevent hot cinders from rolling from the hearth to wood flooring, and to prevent combustible materials, e g. paper, cloth cuttings, etc , from finding their way on to the hearth Metal fenders are generally suitable, but in cabinet makers' and similar workshops a fixed brick or concrete fender at least 12 in in height is desirable.

Converted fireplaces and flues. Fire hazards often arise because a fireplace or flue which was suitable for its original purpose has been converted to another use A flue adequate for a dwelling-room fire cannot safely be used for, say, a fish fryer's stove, a laundry ironing stove, or a central heating boiler, especially if oil fired, as the heat from these appliances is so much greater than from an ordinary fire When an old-fashioned grate set some inches above the hearth is replaced by a sunken or well fire the hearth gets very much hotter In old buildings, including some country mansions, joists which have not been "trimmed" and pass under the hearth have been ignited by reason of such inattention The fault is not in the type of fire but in the carelessness or ignorance of those installing it, who do not ensure that the conditions are suitable

When a fireplace is disused it is not uncommon for it to be made up with wood or paper, but this is unsafe as sparks or burning soot from an adjoining flue may, in the event of the flue separations being defective, fall through the disused flue and ignite accumulated soot or the boarding up. The safe method of dealing with a disused fireplace is first to clear the flue of soot and then cover the opening with sheet metal, or, if desired, with brickwork.

Drying in front of fires. Housewives, furriers, and others often dry articles in front of open fires Sparks may fly on to these articles A wire guard, which is compulsory when children under seven years of age are present, tends to prevent inflammable materials from coming into contact with the fire.

PIPE STOVES

A large number of types of stoves burning coke, coal, or anthracite are included under this heading, the common feature being that they all have a pipe for carrying away smoke and providing a draught. All are provided with means of varying the draught by opening or closing dampers and some, known as *slow combustion stoves*, are so constructed that they will burn for many hours without attention

The features of hazard are—

Base. The London Building Act provides that the floor under a stove which is not heated by gas shall for a space of 18 in. around the same be of an incombustible and non-conducting nature not less than 6 in thick Where the flooring is of wood a slab of stone or concrete or of bricks cemented together must be provided. Insurance offices, usually, are satisfied with bases of these materials 2½ in. thick. A sheet of metal is useless as a floor protection as heat is conducted through it.

Fender. The provision of a fender is desirable to prevent hot ashes and cinders from falling on to the floor with the possibility of igniting any wood flooring or combustible matter, such as paper, waste, etc. In some situations, e.g printers', tailors', and woodworkers' shops, a fender 12 in in height is a necessity. Where articles are dried by the heat from the stove, e g. in a laundry, a substantial wire guard should be supplied in order to prevent any articles from coming into contact with the stove or its pipe.

Smoke pipe. Fire offices often impose an additional charge when a pipe exceeds a specified length—usually 3 ft. This is not only on account of the hazards of the piping, but is intended to persuade persons installing stoves to place them near walls, where it is thought there is less likelihood of combustible matter coming into contact with them than if they were placed in the middle of a room, perhaps surrounded by work benches. There are, how-

ever, several hazards inseparable from these pipes, and the shorter they are the better, whether they vent into a brick flue or to the open through the nearest wall The London Building Act requires pipes for conveying smoke or other products of combustion to be fixed not nearer than 9 in. to any combustible materials. They should be rigidly fixed with substantial stays and certainly not merely suspended by wire from ceilings. Where the metal flue passes through a floor, wall, or roof it is necessary to cut away any woodwork within 9 in of the pipe and to fill in the space with a sheet of iron, the pipe passing through a hole cut in the middle of the iron plate Fire offices generally approve an alternative arrangement by which the smoke pipe passes through a collar formed by an earthenware drain pipe. This necessitates only sufficient wood being removed to accommodate the earthenware collar, and provided the metal smoke pipe is so fixed that there is an air gap between it and the collar, the method is fairly satisfactory.

Soot accumulates in the piping, especially at joints and in horizontal runs Should the soot be ignited, the pipe may become hot enough to set fire to woodwork or other combustible material near it, or burning soot or sparks may escape from corroded or split portions of the piping or from badly fitting joints and fall on to combustible matter.

Cast-iron piping permits better joints to be made than thin sheet metal, which, moreover, is subject to corrosion by coke fumes and is also attacked by the weather at the point where it passes through the roof, causing holes through which sparks may be emitted and rest among the roof timbers.

Woodwork near a stove. A stove should not be installed within 2 to 3 ft, according to the heat given out, of any woodwork, but if it is unavoidable to do so the wood must be protected by sheet iron or asbestos so fixed that there is an air space between the wood and the sheeting.

Inflammable gases, vapours, and dusts. Where these are likely to be present no type of pipe stove is permissible.

Portable Coke Fires

These fires, which are variously known as cokels, devils, and braziers, are often constructed by punching holes in the sides and bottom of an ordinary bucket. They are a very hazardous form of heating, and should only be allowed in exceptional cases, e g. foundry casting shops. They emit sparks, are quite unprotected against contact of combustible materials, and are liable to be knocked over.

CHAPTER XIII

LIGHTING AND HEATING BY GAS

COAL gas. Installations, appliances, high-pressure gas, storage of gas—Calor gas—Acetylene Acetylene installations and generators, storage of carbide, dissolved acetylene—Petrol air gas

COAL GAS

A NUMBER of gases are capable of use for lighting and heating purposes, but in practice it is so seldom that any but coal gas is used that this is referred to without ambiguity simply as "gas." It is produced by the destructive distillation of coal in retorts, and generally a proportion of water gas is added It is rarely produced by individuals for their own use but by public authorities and companies who supply it to consumers by way of mains.

The hazards of gas can be considered under two heads: the risk in distributing the gas throughout the building and the risks at the appliances using it. The predominant feature in both cases is that in the event of leakage and mixture with air in proportions of gas to air between 8 per cent and 23 per cent an inflammable and explosive mixture is formed which can easily be ignited by any naked flame, fire, electric spark, or even by some ignorant person looking for the leakage with a lighted candle or match. Fortunately gas has a pungent smell, which discloses its presence.

GAS INSTALLATIONS

The first requirement to avoid trouble is that the installation is carried out by reputable contractors and that first-class materials are used. All piping should be iron, steel, or copper, and separated by spacing or insulation from any electrical conduit, cable or appliance. Fires have occurred where, due to electrolysis or electric arcs, gas piping has been punctured and the leaking gas ignited. Whilst a type of thin lead piping known as "compo" is easy to install, it has nothing else to commend it. It is soft, easily damaged, both during its erection and in use, and soon deteriorates. Should gas, escaping from a leak or puncture accidentally made in the pipe, become ignited, the heat melts the adjacent portions of piping and permits more gas to escape. Moreover, in any fire, whether caused by the use of gas or in other ways, compo piping easily melts, permitting escaping gas to feed the fire.

Whenever possible rigid piping should be used but, in the case of portable appliances, e.g. irons, pokers, rings, coppers, this is

not practicable. Thin rubber tubing is not to be recommended as it is easily ignited, perhaps by a "back-fire," when it burns freely, but stout unkinkable rubber tubing is not so objectionable, unless it is likely to come into contact with flames or heated surfaces, in which case good quality metallic tubing should be employed. In any case the connection used to join the tubing to the supply and to the appliances should not be of the push-on type, but should be screwed to prevent accidental disconnection. Undoubtedly the best method is to use good quality metallic tubing, which is screwed at one end to the appliances and at the other to a plug This is fitted when required into a socket secured to the wall and connected permanently to the supply. All disused piping should be plugged off with a proper screwed cap or plug and any disused tubing should be removed

Meters should be placed in accessible, ventilated positions and clear of combustible materials A fire near the meter is likely to melt the supply piping, which at this point is of heavy lead to permit of easy installation and removal of meters. A cupboard under the staircase cannot be regarded as a suitable situation

Sometimes the manager of a premises will assert with the pride of rectitude that "gas and electricity are shut off at the meters every night" While there is a good deal to be said for this practice, there is an objection to it, inasmuch as a subsidiary tap—say to a soldering stove—may have been left on at night When the main stop cock is opened next morning gas may escape from the stove unobserved. Similarly, electric apparatus may unwittingly become "alive." There is, however, no doubt as to the desirability of having the main gas stop cock and electric switches plainly indicated in such a place that they are accessible to the fire service without delay, yet not easily reached by unauthorized persons It is necessary that such cocks be maintained in good order—cases have been known where, from lack of use, they have become so corroded that when required in a hurry they cannot be turned. Any taps likely to be accidentally knocked on should be of the "drop handle" type or have removable keys.

Reference was made in the previous chapter to the hazards of lighting up (which can in the case of gas be obviated by the use of by-pass lights), naked flames, proximity of combustible materials, and the presence of inflammable gases, vapours, and dust, any or all of which are applicable to gas lighting and heating.

Gas Appliances

The appliances commonly used include the following and hazards *additional* to those already mentioned are noted.

Gas burners for lighting. Occasionally a burner using a luminous flame is found, but almost all burners are of the type using a non-luminous flame to heat a mantle (either upright or inverted), which gives a much better light and more heat than a luminous flame. It is possible for glowing fragments to fall, perhaps on to inflammable material.

Where a gaslight exceeds 175 candle-power the Fire Offices Committee's regulations provide that a metal heat deflecting shield at least 10 in. in diameter must be fixed above the lamp, not less than 24 in. from a non-fireproof ceiling, beam, joist or floor, unless such ceiling, etc., is protected with plaster or sheet asbestos at least 30 in. in diameter, when the shield need only be 12 in. from the ceiling. The pipe, whether flexible or not, connecting an incandescent lamp to the gas supply must be of metal with metal connections.

Gas fires use a row of bunsen type burners to heat asbestos "elements" to redness. If not installed on a properly constructed hearth, a stone slab should be provided to protect wood flooring under and in front of the fire. Portable gas fires need flexible tubing, are liable to be overturned, and may be placed near combustible materials

Gas radiators consist of a number of vertical metal columns set above a row of bunsen type burners which heat the air in the columns and thus the columns themselves. The term *radiator* is a misnomer as the atmosphere of the room is warmed by contact with the hot metal columns—*convector* would be a more descriptive term. In some gas radiators a small quantity of water is contained in the bottom of the columns, which are then heated not by air but by steam vaporized by heat from the burners. Gas radiators should stand on a stone or concrete slab to protect the wood flooring but, in general, are safer than open gas fires as the burners are more or less enclosed in the base and so there is less likelihood of inflammable material coming into contact with them.

Garage type gas radiators. The enclosure of the ordinary radiator is not sufficient to exclude inflammable vapours, but for use in garages and other places where such vapours are likely two special types are obtainable. In both types the burners are entirely enclosed in the base of the radiator, the difference lying in the manner in which the air necessary for the operation of the burners is introduced In one type it is permitted to enter and to leave only through orifices protected with wire gauze on the principle of the *Davy miner's safety lamp*. Any inflammable mixtures of vapour and air which enter through the orifices may ignite and burn inside the radiator, but the flame will not travel through the gauze because the wire cools the mixture below its

ignition temperature. One disadvantage which attends this type is that the gauze may become clogged or broken, in which state it is useless The other type has a metal duct or flue running from the chamber in which the burners are enclosed to the open air; thus air freely passes to and from the burner chamber but the atmosphere inside the building is excluded. In both types access to the burners for lighting them in the first place is obtained by the removal of a screwed cap. A by-pass jet is allowed to burn continually so that the burners may be re-lit without removing this screwed cap It will be appreciated that when the cap is not in position the exposed opening renders useless the safety precautions and the radiator is at the same disadvantage with regard to inflammable vapours as any ordinary radiator.

Gas rings are used for many purposes such as boiling kettles and heating glue pots, irons, etc. It is common to find them on wood benches or shelves which are either bare or covered only with thin metal or asbestos cement sheeting. This is unsatisfactory· the removal of the covering often discloses that the woodwork beneath is charred A base of stone or concrete 2 in thick should be provided and the whole placed in a metal tray with sides sufficiently high to prevent combustible matter from being swept against the ring Alternatively, the ring can safely be placed on a metal stand at least 12 in in height Flexible tubing is generally used to connect gas rings, but rigid piping is much safer, both inherently and because it ensures that the ring will remain on its base.

Gas heated enamelling and other ovens. See p. 105.

High Pressure Gas

Gas at a pressure greater than the normal is often employed for lighting streets or large buildings, as considerably more light can be obtained from the same quantity of gas by increasing the pressure at which it is burned. Generally the gas is supplied at normal pressure to the premises in which it is to be used, where it is compressed by means of a rotary pump to which an automatic regulator is attached in order to prevent fluctuations Little hazard is to be apprehended from these compressors and they are allowed by insurance companies without special conditions provided (*a*) they have no storage capacity or (*b*) they have a storage capacity not exceeding 10 cubic feet and are placed in a separate compartment

Storage of Gas

It is unusual for gas to be stored elsewhere than at gas works Until recent years all gas holders were of the watersealed type, the appearance of which is familiar to everyone. An inverted

circular steel shell rises and falls, according to the quantity of gas contained, in a water-filled pit or tank below ground level. The water acts as a seal to prevent the gas from escaping. These gas holders may have a single "lift" (or section) or several lifts arranged telescopically.

Most of the gas holders in this country are of this type, but there are now also a number of "waterless" gasholders. These are much larger than the waterseal type and consist externally of a fixed polygonal shell of steel plates. The gas is contained between the concrete base and a "piston" or false roof which fits closely to the sides of the shell and rises or falls according to whether gas is being admitted or withdrawn. It is important that the gas shall not leak from the lower portion into the air space above the piston, as were this to occur an explosive mixture would be formed capable of ignition by a spark or flame This is a hazard not present in the waterseal type and to prevent such leakage a trough of tar is attached to the periphery of the piston, providing a film of tar (or tar seal) between it and the sides of the shell.

The safety of either type is dependent on the gas being precluded from mixing with air, and the main danger to be apprehended is that of a fire or explosion, occurring nearby, so severely damaging the gasholder that such mixture could take place. The large size of the waterless gasholders, ranging from one to ten million cubic feet, is a disadvantage from this point of view.

Other Gases Used for Lighting and Heating

Apart from coal gas, three other gases—acetylene, petrol-air gas, and butane—are used for lighting purposes, but as they are less convenient than coal gas their use is restricted to those premises which are outside the limits of coal gas supply mains. The grid system now makes electricity available in all but the most remote parts, and the use of the gases mentioned is on a very small scale.

Calor Gas

In remote places where coal gas is unobtainable it is possible, nevertheless, to enjoy the conveniences of gas lighting and heating by using calor gas. This is a butane mixture supplied in cylinders about 23 in. high by 13 in. diameter in which the gas is in liquid form, being under a moderate pressure of about 23 lb. per sq. in. (one-and-a-half atmospheres) When the pressure is released the liquid changes to gas, in which form it is distributed to the appliances. Practically any equipment used for coal gas can be adjusted for calor gas, and the hazards of the various appliances are similar.

Several points are worth noting. As the gas is very penetrating, great care must be taken with joints and taps, neither red lead, solder, nor ordinary rubber being allowable Mixtures of 1·9 per cent to 8·6 per cent of the gas with air are inflammable, so that a very small leak may be dangerous Pure butane has no smell and an odorant is added to facilitate detection of leakages Where a number of appliances (e g lighting burners, cooker, etc) are installed, copper or iron piping is used to convey the gas from the cylinder to the appliances, but when only one or two appliances are to be supplied flexible tubing is used. Ordinary rubber is attacked by the gas, but a special rubber may satisfactorily be used, although from a fire prevention viewpoint metal tubing and connections are better Spare cylinders should, where possible, not be kept in the main buildings

Other liquefied petroleum gases (e.g propagas, bottogas) may be regarded somewhat similarly.

ACETYLENE

When calcium carbide—a grey substance manufactured by combining coke dust and lime in an electric furnace—and water are brought together heat is developed and a gas known as acetylene is generated, leaving behind spent lime in the form of sludge. Acetylene gas forms an inflammable and explosive mixture with air in proportions ranging from as low as 3 per cent acetylene—97 per cent air to as high as 82 per cent acetylene—18 per cent air. This range is greater than that of any other gas, and consequently acetylene must be regarded as one of the most hazardous gases.

Portable lamps are sometimes used for lighting and heating purposes, but generally apparatus, similar in appearance but different in details of construction to coal gas apparatus, is supplied with acetylene by fixed piping. The hazards at the burners and in distribution are similar to those of coal gas, i e. flexible and soft metal piping, lighting up, naked flames, proximity of combustible materials, and the presence of inflammable gases, vapours, and dusts As acetylene will form inflammable mixtures with air in almost any proportion, even a slight leak is likely to have grave consequences; fortunately the gas has a distinctive odour, rather like garlic. No metal containing more than 80 per cent of copper should be used in any pipe, valve, or other fitting as the action of acetylene on copper is to form copper acetylide, which is a highly explosive compound readily detonated by heat or friction.

Acetylene is not supplied through mains by supply companies like coal gas, but cylinders of this gas can be purchased or, more usually for lighting purposes, a generating plant is installed.

Acetylene generators are of various types, the main difference being in the method by which the water and carbide are brought together. The most common form is that known as "water to carbide" A cylindrical tank filled with water stands over a generating chamber containing carbide. Water from the tank is permitted to flow on to the carbide, thus generating acetylene gas, which is cooled and washed by passing through the water in the tank and is collected in an inverted cylinder, floating in the water, known as a rising bell gasholder. The gas causes the bell to rise and in so doing automatically to cut off the water supply to the carbide, thus stopping the generation of gas. As gas is withdrawn from it, the bell falls, actuating the lever of a ball valve which permits water to flow again into the generating chamber. The gas, on leaving the bell, passes through a safety outlet to a purifier and thence to the supply piping to the appliances at which the gas is burned.

In the "dipping" type of generator, carbide contained in a wire basket is, by the action of a rising bell, alternately dipped into and removed from water. It is important that after cleaning or re-charging the basket it should be filled with new carbide and none of the spent charge allowed to remain, as the interior of one of the lumps may still be at a temperature sufficient to ignite acetylene.

A third type—"carbide to water"— allows small pieces of carbide to fall into a water container. Sometimes pieces of carbide become wedged in the feed mechanism and unless care is exercised a spark may be caused by efforts to remove it.

In considering the fire hazards the extremely explosive nature of acetylene must continually be borne in mind.

Generators. Considerable heat is evolved in the generation of the gas and faulty design of apparatus may permit high temperatures and unsafe pressures to develop, after which an explosion may occur. Only apparatus made by reputable firms and certified to conform to the standards of the British Acetylene Association should be used, and the detailed instructions supplied by the makers should be posted near the generator.

Situation. Generating plants should be either in the open or in a well-ventilated shed used for no other purpose and having no communication, other than by double fireproof doors, with any other building. Only authorized persons should have access to the shed

If artificial lighting and heating are required in the generator house, only those forms described on page 68 as suitable for situations where inflammable gases are likely should be employed.

It must be remembered that during frosty weather the water is likely to freeze if the generator house is unheated, and care

must be taken to ensure before starting up that the apparatus and pipes are clear of any ice which may have formed either because the generator has not been drained or due to condensation Frozen generators, etc , should be thawed by means of hot water, certainly not by fire or pieces of hot metal.

Naked lights. No naked lights may be taken into a generator house or near a generator in the open, and smoking should be strictly prohibited.

Repairs. Before repairs and overhauls are commenced care must be taken to ensure that all parts are free from gas. Filling with water is a good precaution. Periodical overhauls are recommended

Portable generators must only be used in very well-ventilated places and must be remote from any possible source of ignition of acetylene gas

Sludge (spent carbide). It often happens that the centres of large lumps of carbide are not exhausted when withdrawn from the generator. If the sludge is placed in a damp situation acetylene will continue to be evolved and an explosive atmosphere may arise Care, therefore, should be taken that the sludge is deposited in a safe, remote place in proper settling tanks

Portable acetylene lamps are sometimes used for lighting purposes. Most of these are so arranged that water drips into a generating chamber containing the carbide, and the burner is attached to the generator. The Fire Offices allow the use of these lamps provided the apparatus holds a charge of not more than 2 lb of carbide, but for use in the open and in buildings in course of erection a charge exceeding 2 lb. (the average is 18 lb) is allowed The usual objections to portable apparatus (e g. risks of overturning, etc) apply.

Storage of calcium carbide. Bearing in mind that moisture, even the moisture of the air, will cause calcium carbide to give off acetylene, care in storage is necessary The storeroom should be a detached, perfectly dry, well-ventilated shed in which the metal airtight drums in which carbide is stored are raised above the ground. Steel tools must not be used to open the drums as a spark may be caused and any acetylene gas in the drum ignited. Special tools with bronze points should be used No smoking or naked flames may be permitted in the vicinity and only forms of lighting described on page 68 as suitable for situations where inflammable gases are likely should be allowed. A prominent warning of the nature of the store should be displayed in order that water shall not be used in attempts to extinguish a fire or for any other reason.

A licence issued by the local authority is required for storage

of more than 28 lb. of carbide, and a notice must be posted detailing the conditions under which the licence is granted. Under the Petroleum (Consolidation) Act, 1928, and the Petroleum (Carbide of Calcium) Order, 1929, the storage of smaller quantities is subject to the conditions laid down in the Order.

Dissolved acetylene. Although the usual method of providing acetylene for lighting and heating purposes is by means of a generator, it can be purchased in cylinders.

At pressures over 3½ lb. per sq. in acetylene is spontaneously explosive and its use or storage in this state is prohibited by law. It is, therefore, impossible to compress it in cylinders in the way that oxygen or hydrogen is treated. Its conveyance would be difficult indeed were it not for the fact that when dissolved in acetone it can be subjected to considerable pressure without having explosive properties, under this treatment it is known as dissolved acetylene. A cylinder is partly filled with absorbent material soaked in acetone, and the acetylene gas is then pumped into the cylinder where it is absorbed by the acetone. Under the Explosive Acts a pressure not exceeding 150 lb. per sq. in. may be applied, in which case about 100 cub. ft. of acetylene could be contained in the usual size cylinder. In practice lower pressures are used. Although the acetylene is not spontaneously explosive in this state, the cylinders must not be subjected to rough usage, shocks, or high temperatures. Precautions which should be taken when acetylene is used for metal cutting and welding (for which purposes it is more used than for lighting) are dealt with on pages 132–134.

Petrol-air Gas

This method of lighting and heating is obsolescent, but occasionally installations are found in inaccessible places. In order to burn satisfactorily it is necessary for the mixture of petrol vapour and air to contain about 2 per cent of petrol vapour.

There are two types of installations, known as "weak" and "rich" mixture plants respectively. In the weak mixture type a mixture of 2 per cent petrol vapour 98 per cent air is made and conveyed through piping to burners, which must be fitted with gauze diaphragms, as otherwise the flame might "flash back" to the generator because the mixture in the piping is an inflammable one. In the rich mixture type a mixture of 6 per cent petrol vapour 94 per cent air is made and conveyed to burners, where sufficient air is added to reduce the proportion of gas to the requisite 2 per cent This method has the advantages that a final adjustment for strength can be made at the burners, and that the mixture in the piping and generator is too rich to be explosive.

In the event of leakage of a weak mixture, which is itself explosive, it will be diluted by the air of the room and become too weak to be dangerous, while a leakage of rich mixture, which is itself incombustible, may become mixed with air in such proportions as to become explosive! It is an open question which method is the safer.

The arrangement and hazards in distribution and at the burners are similar to those for coal gas, i.e flexible and soft metal piping, lighting up, naked flames, proximity of combustible materials, and the presence of inflammable gases, vapours, or dusts.

The generator consists essentially of a carburettor in which petrol is vaporized and mixed with air in constant proportions The mixture passes to a gas bell, which automatically controls the starting and stopping of the apparatus, and thence to the supply piping to the burners.

The small tank of petrol, usually 2 or 3 gallons, attached to the plant, can be filled by hand, or a storage tank can be fixed to the outside of the building and connected to the small tank by a pipe with a stop cock near the storage tank

Most plants are weight-driven (i e they are operated by weights similarly employed to those which drive a grandfather clock), but where, although electricity is available, it is desired to use petrol-air gas, perhaps for cooking and heating, the plant can be driven by electric motors

Although the hazard of these plants is by no means so great as that of an acetylene generator, similar precautions should be adopted in the generator house to those described under "Situation" on page 83

CHAPTER XIV

LIGHTING AND HEATING BY ELECTRICITY

PRINCIPLES—Conductors and circuits· short circuits, fuses, arcs, workmanship and materials—Inspections—Wiring systems. joints, switchboards, switches, plugs and socket outlets, adaptors—Lighting appliances: incandescent lamps, arc lamps, luminous discharge tubes—Heating appliances radiators, tubular heaters, irons, pilot lights—Inflammable atmospheres

IT is not possible to compress into a reasonable space an explanation of the theory and principles of electricity, a subject which demands a library of its own. This chapter must be confined to a mention of the more common appliances and an explanation of how fires are caused by their use. It is assumed that most readers will have a knowledge of the elementary principles of electricity, but for those whose knowledge is rusty there are several points which must be mentioned in order that the various hazards will be appreciated.

Electricity is a force which man utilizes to do work for him, such as heating a wire to red heat to provide warmth or heating a filament to incandescence to give light It is usual to compare the flow of electricity with the flow of water, as it is convenient to think of electricity in this manner although the analogy is not complete. Pressure (measured in *volts*) and rate of flow (measured in *amperes*) may be thought of in a similar manner to the pressure and rate of flow of water.

CONDUCTORS AND CIRCUITS

Substances through which electricity flows easily are known as *conductors*, and those which oppose its passage are called *insulators*. A cable or a flexible cord consists of a conductor (e.g copper wire or wires) through which an electric current can pass, enclosed in an insulating covering (e.g rubber) which prevents the electricity from leaking. Excessive pressure will cause the insulation to break down and permit leakage in a similar manner to excessive pressure of water causing hose to burst.

Electricity will flow only in a closed circuit, i.e. there must be a conductor from the generator to the appliance in use and another by means of which it can return to the generator. These will be referred to as positive and negative respectively, although in certain cases this is not a correct description. As electricity flows only in a closed circuit the current can be started or stopped by closing or opening the circuit at any point, e.g. by using a switch.

As no conductor is perfect, the current has to overcome some resistance (even as water has to overcome friction in pipes) and the energy thus spent is shown as heat. The longer the conductor or the thinner it is or the poorer the conducting quality of the material used, the greater is the resistance, and therefore the greater the heat which arises. The relationship in the circuit between pressure and resistance, i e the combined resistance of the wiring and of all appliances which can be included in the circuit, must be such that the current does not exceed that which it is safe for the wiring to carry. Actually the current is proportional to the pressure (electromotive force) divided by the resistance. The amount of heat produced is directly in proportion to the resistance multiplied by the square of the current. Thus, if five times the normal current flows the heating effect is twenty-five times as great, e g when a circuit is grossly overloaded by the addition of appliances. Such heat may be sufficient to lead to breakdown and subsequent ignition of the insulation

One of the most important features from a fire prevention point of view is that there shall be no escape of this heat producer —electricity—and for this reason all conductors must be efficiently insulated The two main hazards of leakage are short circuits and arcs

Short circuits. Should the insulation break down or any other circumstance (such as a nail driven into a wall touching both conductors) allow current to flow directly from the positive to the negative conductor without passing through the appliances in the circuit the current will take this path of less resistance in preference to its appointed route, and as there is less resistance, greater current will flow with the accompaniment of much greater heat than was intended. When the current leaks from the positive conductor and finds its way back to its source, not through the negative conductor at all but by way of earth, the type of short circuit is known as an "earth."

Fuses. To limit the current which can flow through a circuit fuses are provided These may be short lengths of soft wire placed in incombustible holders and so constituted that they will fuse or melt should excessive current flow, thus breaking the circuit and stopping the flow of electricity before the wiring can become dangerously hot

When a fuse "blows" it suggests that there is a fault in the wiring or the appliances connected to it, if when the fuse is replaced by a new one it blows again the suggestion becomes a certainty. The proper procedure then is to rectify the fault. If the fuse were replaced by a larger one, or, as is unfortunately sometimes done, by ordinary thick wire, the protection which

should be afforded by the fuse acting as a safety valve is lost

It is essential for safety that all circuits are properly protected by fuses. For lighting purposes the fuse should be such as to be melted in a minute or less by a current equal to twice the rating of the smallest cable protected by it.

Many so-called electricians imagine that provided proper fuses are supplied, it is impossible for the wiring to overheat, but this is not correct If wiring becomes corroded its effective size is reduced and in this state it is not able safely to carry as large a current as it could carry in its original condition. The fuse, however, would still permit as large a current to flow as it did originally, and this current, although safe enough with the wire when new, may be sufficient to overheat the wire when its size has been reduced by corrosion If the corroded wire then breaks, a spark or arc is formed. Owing to the resistance of the air in the gap between the broken ends, the current may not be large enough to blow the fuse, but yet be enough to maintain the arc, which may be regarded as a continuous spark.

Arcs may similarly occur if positive and negative conductors, the insulation of which has become useless through age or misuse, momentarily come into contact with each other and then separate, or, if a positive conductor touches and then parts slightly from earthed metal, e g. a gas pipe. Arcs can also occur at badly-made joints, at switches and elsewhere They have a very high temperature and combustible materials near them are easily ignited.

Workmanship and materials. It can safely be asserted that most electrical fires are caused by defects in wiring and fittings. Perhaps the materials used were not of good quality or "economy" was exercised in utilizing conductors barely sufficient to carry the required current, without consideration of the fact that consumers almost invariably wish to add further appliances subsequently. Foresight in providing reasonable numbers of socket outlets would often obviate overloading in the future. Bad workmanship may have left joints in an unsafe condition or good cable may have been damaged during installation.

Too often, although the original installation is satisfactory, alterations and extensions are made by incompetent persons Even if the wiring is reasonably done the extension may result in overloading and consequent overheating of the original wiring, but frequently extensions are made with flexible cords There are various grades of flex ranging from poor stuff, unsuitable for any purpose, through types appropriate for use where no mechanical damage is likely, e g for connecting lampholders to ceiling roses, to types of high insulation cords with protective coverings

suitable for use with portable appliances. The higher grades are permissible for temporary extensions, but the danger arises that an extension originally intended to be temporary often becomes a permanent one. It is good practice to regard any form of flex as unsuitable for fixed wiring It must not in any case be run out of sight (e g. behind fixtures or under carpets), and should be supported on porcelain hooks or cleats, certainly not by nails or ordinary staples.

Inspections

Electric supply undertakings carry out a test of an installation before they supply current, but when that has been done they appear to take no interest in the installation apart from reading the meter and collecting the money. It has been suggested that they should be obliged to make periodical tests, and while it may be open to question whether it would be reasonable to impose this duty on the undertakings, there is no doubt that many fires would be prevented by regular inspections and tests

All installations should conform in every detail to the "Regulations for the electrical equipment of buildings" of the Institution of Electrical Engineers, which are supported by insurance companies and supply undertakings The Insurance Surveyor or Fire Service Inspector who is called upon for a report on a premises has not available, at the time, apparatus for making a test, but there are some features which may be observed during a cursory inspection to enable a decision to be made whether a detailed examination and test are desirable. It is not possible to state the period during which an installation may be regarded as safe, as this depends not only on the quality of the materials used and the degree of workmanship in their installation, but also upon whether the wiring has been subjected to heat or damp and upon the other conditions prevailing It may, however, be suggested that electrical installations over twenty years of age demand investigation

Wiring Systems

Bare wiring. It is unusual for bare conductors, i e. those without an insulating covering, to be used, but where they are installed they must not ordinarily be accessible to unauthorized persons, must be carried on effective insulators, adequately spaced, and out of contact with any part of the building.

Cleated wiring (exposed). Braided vulcanized india-rubber cables can be used without casing or conduit providing they are open to view throughout, and are supported on effective insulators so spaced as to prevent the cables coming into contact with

each other or with any part of the building. Where passing through floors, walls, etc., they must be enclosed in metal or other suitable conduit.

Metal-sheathed cables must be supported by types of clips, saddles or clamps which will not damage the cables and so spaced as to prevent sagging. The sheathing must be electrically continuous and earthed

Tough rubber-protected cables are combustible and once ignited the rubber burns freely. They must be supported similarly to metal-sheathed cables.

Metal conduit. It is probable that for general use the safest form of wiring is that in which the cables are enclosed in screwed metal conduit The conduit must be earthed and must be electrically and mechanically continuous, either by means of screwed joints or of grips to retain rigidity. Inspection and connection boxes are of metal and connected by screwing the conduit into the side of the box. Slip socket conduit is unsatisfactory as the lengths of conduit may become separated and the rough edges may damage the insulation of the cables All conduits must be erected to avoid as far as possible condensation of moisture, which would rust the conduit and cause the cable insulation to deteriorate.

Wood casing should be secured by screws and used only in dry situations. The casing should not be larger than necessary. It is, of course, combustible, and it is possible for nails to be driven into it accidentally and damage the cables inside.

Flexible cords should be discouraged as fixed wiring, but if installed, for sub-circuits only, they should be of the high insulation type, in view for the whole of their length and supported on effective insulators at intervals of not more than 3 ft.

In every form of wiring the cables, conduit, etc., must be adequately protected against mechanical damage, especially within 6 ft of the floor. Where passing through floors or walls the holes must be made good with incombustible materials so that space is not left through which fire might spread Cables and conduit must be prevented by spacing, insulation, or other means from coming into contact with gas and water pipes. Fires have occurred because a gas pipe, particularly "compo" piping, has become so affected by electrolytic action as to be punctured and the escaping gas has been ignited by an electric spark. A gas pipe must on no account be used as an "earth." In damp situations supports and fixings of insulators should be of non-rusting material.

Joints, if badly made, are a cause of overheating of wiring and

of arcs When, as sometimes happens, two cables are merely twisted together, covered with insulation tape and tucked away out of sight, the only question is how long it will be before trouble arises Joints involving a flexible cord may only be made by means of mechanical connectors, but all other connections between cables may be made either by means of a mechanical connector or by a soldered joint. All joints should be enclosed in joint boxes or fittings suitable to the form of wiring. The fewer the joints the better from the fire prevention point of view.

Switchboards should be of a durable, non-ignitible and non-absorbent nature and placed in a dry, well-ventilated situation where rubbish and other combustible materials cannot accumulate

Fuses must be so arranged that no molten metal can come into contact with combustible materials. The size of the fuse is determined by the *smallest* cable in the circuit in order that all cables are protected against overheating. Replacing a blown fuse with a larger one means that the wiring may be unprotected

Switches must have a quick break action or an arc may be set up between the contacts A single pole switch must be fitted to the live conductor: a double pole switch operates on both. Switches should not be fitted within 4 ft 6 in of the floor in garages on account of the possibility of the presence of petrol vapour, which is heavier than air

Plugs and socket-outlets. The appearance of plugs and sockets for connecting portable appliances to the supply are well known, but the hazards associated with them are not so well appreciated. Many portable appliances are provided with a built-in switch by means of which the apparatus can be switched off If this is done the flexible wiring connecting the appliance to the plug remains alive, and as such flexibles are subject to much wear it is not surprising that fires occur by reason of flexible cords becoming damaged They often run over, or even under, carpets and rugs, and should a short circuit occur in them, or some of the strands of wire of which they are composed break, leaving the few remaining intact to carry the whole of the current, the insulation may ignite and in turn fire combustible materials in contact with it. All socket outlets should be provided with switches in order that the flexible cord need not be alive when the appliance is not in use. Such switches are, of course, of no avail unless they are operated and unless they are inserted in the live conductor.

To reduce the possibilities of shock, three-pin plugs, which enable portable appliances to be earthed, are preferable to the

two-pin type, and, moreover, the plugs cannot be inserted "the wrong way round." A socket outlet should not be fitted in or near a floor, where it could be affected by water used in washing the floor.

Socket-outlet adaptors. When it is desired to supply several appliances (e g a radio set, a table lamp, and a fire) from one socket a three-way adaptor can be used, but the practice is open to objections, as one of the appliances may be switched on inadvertently One of the many fires which have been caused in this fashion happened in an office where an electric fire and a duplicating machine were operated from one switch-controlled socket with a two-way adaptor The fire had been in use, and after it had been duly switched off at the socket it was placed in a corner against some papers stacked on the floor Subsequently a typist plugged into the unoccupied side of the adaptor the plug of the duplicator and switched on the current, which of course caused not only the duplicator but the fire as well to become alive. The papers stacked against it ignited and as a result of the fire the girl lost her life. A separate socket should be supplied for each appliance in use It is not a good practice to connect appliances to lampholders, as not only is the wiring liable to be overloaded but the connection made is a poor one

LIGHTING APPLIANCES

Incandescent lamps. As the filament is enclosed in a sealed glass globe and there is no "naked" light, electric lamps are safer than any other source of light, but it must not be overlooked that with high-power lamps the glass may become hot enough to ignite inflammable materials in contact with it. Celluloid is particularly dangerous, but paper or textile lamp shades and curtains, etc., should not be allowed to touch the lamps. When high-power lamps are enclosed in recesses to provide concealed lighting effects there is a possibility of woodwork becoming dangerously heated.

Arc lamps are now seldom used for general lighting in buildings, but may be encountered in connection with the photographic, printing, and other trades. The light is emitted by an arc burning between the tips of two nearly touching carbon rods. Fire hazards arise by reason of the very high temperature of the arc and because, as the carbon rods burn away, fragments of incandescent carbon are liable to drop. Open arc lamps must have a metal reflector rigidly attached beneath them, the arc being at all times set below the upper edge of the reflector The reflector should project 21 in. beyond horizontally on every side.

Enclosed arc lamps which have double globes surrounding the

arc are safer in hazardous situations than open arcs. Generally the breakage of the inner globe causes the arc to be extinguished. The resistance coils which are necessary in connection with arc lights become hot and should therefore be placed well clear of woodwork in a well-ventilated position.

Luminous discharge tubes are hermetically sealed glass tubes containing a gas (often neon gas) which becomes luminous when a current is passed through it The first of the two main types of these tubes (those known as cold cathode lamps) are not used for indoor lighting but are employed for advertising signs, outlining buildings, and so on. They require a very high voltage and should, therefore, not be accessible to unauthorized persons. Most local authorities insist on the provision of an emergency (firemen's) switch fixed in a prominent position not more than 9 ft. from the ground, which can be used by firemen to cut off all current from the sign, thus removing danger of shock due to the use of water jets. The transformers which are necessary in connection with these signs should be in metal cases clear of combustible materials The other type, known as hot cathode lamps, operate at ordinary pressures of 230–400 volts, and their appearance is familiar to most people because of their use for street lighting dating from 1932 When the glass or quartz tubes are filled with mercury vapour, the colour of the light emitted is bluish · when sodium vapour is used, brilliant yellow. Much of the radiation of these tubes is in the ultra-violet region and is ordinarily invisible, but some tubes are now coated with fluorescent powder, which renders these rays visible.

Having regard to the efficiency of these lamps it is certain that their use for the lighting of industrial premises will increase rapidly A convenient form is that of a 5 ft long tube. The tubes attain a fairly high temperature, but are enclosed in a glass vacuum jacket to conserve the heat and thus increase the efficiency. It is probable that provided the lamps and the necessary resistances are well clear of combustible materials no particular fire hazard need be apprehended

Heating Appliances

Radiators or fires of the type in which a coiled wire element is heated by the current to redness are the most common. The heat is sufficient to ignite combustible material which comes into contact with the elements, and insurance companies are quite used to claims for trousers and dresses which have been ruined by the wearers standing in too close proximity to the fire. Clothing aired in front of the fire is another frequent subject of claims. As the wire guards provided by the manufacturers of the fires

are seldom of much use, an additional guard should be provided when a fire is used for drying purposes. Portable fires have the disadvantages that flexible wiring must be used, that the fire may be overturned, and that it may be placed near combustible materials. Other, less common, forms of radiator include non-luminous types in which elements completely enclosed in a metal case are heated to about 200° F, i e do not attain red heat, and hot-water radiators in which the water is heated by electric immersion heaters, i e. an element enclosed in a watertight case. These types have the advantage that the external surfaces do not ordinarily attain sufficient heat to ignite combustible materials.

Tubular heaters comprise metal tubes or casings some feet in length, enclosing a heating element on porcelain or fire clay supports, which prevent the element from touching the metal case The tubes are mounted on brackets, usually on skirting boards, and should be so fixed as to be clear of woodwork. Although the elements are not heated to redness and the outer case cannot therefore attain ordinarily a temperature sufficient to ignite combustible material, some care is necessary, as should the tubes become covered (e g with floor waste) the heat would be "bottled up" and dangerously high temperatures attained

Electric irons. Apart from the hazards previously mentioned in connection with flexible wiring and plugs and sockets, there is the added possibility of the iron, while still switched on, being placed and allowed to remain on combustible material. Many of the fires which have occurred in this manner would have been avoided had a suitable stand of thick incombustible material been provided and a pilot light been in use.

Pilot lights are lamps, generally coloured red, installed in the same circuit as an appliance so that the lamp is always alight when the appliance is in use. Irons and cooking ovens should always be provided with these lamps, and the precaution might well be extended to other apparatus which gives no obvious sign when it is alive.

INFLAMMABLE ATMOSPHERES

Where inflammable gases, vapours, or dusts are liable to be present care must be exercised that electrical apparatus cannot provide a source of ignition.

The precautions necessary are set out on pages 68 and 116. Many accidents have occurred through the use of electric portable lamps in garages, inspection pits, and for examining empty drums in which inflammable liquids have been kept

CHAPTER XV

CENTRAL HEATING SYSTEMS

Low-pressure hot water—High and medium pressure hot water—Steam—Unit heaters—Hot air—Steam heated air

The methods of central heating in use to-day include (1) low pressure hot water, (2) high pressure hot water, (3) steam, (4) hot air

In each case the medium employed is heated at a furnace or boiler, and, in each method except that of hot air, piping is provided to convey the medium throughout the building Provided the heating apparatus is situated outside the building or in a fire resisting compartment, the fire hazards depend on the temperature which it is possible for the piping to attain. It will be remembered in this connection that if woodwork is subjected over a prolonged period to temperatures exceeding 300° F. the wood is liable to change its nature and may acquire the property of spontaneously igniting Other substances, too, such as fluff, dust, and waste generally, may come into contact with the pipes and quite apart from the possibility of spontaneous combustion such materials and woodwork become excessively dry and are easily ignited

The practice of insurance companies is to regard low pressure hot water or low pressure steam as non-hazardous but to impose additional charges in premises where high pressure hot water or steam at 300° F. or higher temperature or a fire heated hot air plant is used. The hazards of the various fuels capable of being used in any system are described in Chapter XVIII.

Low Pressure Hot Water Apparatus

The water is heated in a boiler (placed at the lowest part of the building) to which iron piping about 2 in. to 4 in in diameter is connected to form a system through which the water circulates, and which includes radiators to provide heating surface to warm the various rooms The flow of water is maintained because hot water has a specific gravity less than that of cold water. When the water in the boiler is heated it rises through the "flow" pipe to the radiators, where it loses heat and is carried back to the boiler by the "return pipe." The cooled water is then heated again and the circulation continues. Water lost by evaporation is made up from a feed tank which is supplied with water from the mains by a ball valve.

The London Building Act provides that "a hot water installation shall be deemed to be at low pressure when provided with a free blow-off." This may be taken as implying that the system must be open to the air at some point in order that the pressure cannot exceed that due solely to the height of the water in the system The "free blow-off" is generally provided in the form of an "expansion pipe" which is open-ended and terminates over the cold water feed tank.

The importance of the system being open to the atmosphere is contained in the fact that whereas normally the boiling point of water is 212° F , it will not boil until a higher temperature is reached if it is under pressure, e g if the pressure is 19·7 lb. per sq in the boiling point is 227° F , if 66·7 lb per sq in. 300° F. Provided then that the system is open to the atmosphere the only pressure, additional to that of the atmosphere, on the water in the boiler is that imposed by the height of water in the system As each foot of height gives a pressure of ·434 lb. it would be necessary for a building to be 120 ft. in height to enable the temperature to reach 300° F. It can, therefore, safely be assumed that the highest temperature that can be attained in most buildings is far below that figure Moreover, it is not usual for the water to be kept at a higher temperature than 200° F.

The boiler should be in a separate compartment, preferably a fire-resisting one, but often it is installed in a basement without any enclosure. Where this occurs it is possible for stock to be stacked near the boiler or for waste to come into contact with it. Small boilers should in such conditions be treated with the same care as pipe stoves (see pages 75 and 76)

The pipes cannot attain a dangerously high temperature, but care should be taken that paper, fluff, and waste are not allowed to accumulate behind pipes and radiators as they would become very dry in which state they could easily be ignited by ordinary sources of ignition.

High Pressure Hot Water Apparatus

The system comprises one continuous circuit consisting of small bore wrought-iron piping (external diameter $1\frac{5}{16}$ in) extending throughout the building and at one point coiled around an enclosed furnace. An expansion chamber is fitted at the top of the system. The piping is filled with water, the expansion chamber with air, and the whole hermetically sealed When the furnace is lighted the water in the coils passing around it becomes heated and circulation proceeds in a similar manner to that in a low pressure apparatus At the same time, however, the water expands because of the heat and, endeavouring to flow into the

expansion chamber, compresses the air which is there The compressed air exerts a pressure on the water the hotter the water becomes, the more it expands, the more it compresses the air and therefore the greater the pressure which is imposed by the air on the water.

As the water is under pressure its boiling point is not 212° F. but some higher temperature It is common for these systems to be designed to maintain a temperature of about 300° F, but they can, if required, heat the water to 400° or even 500° F

The precautions required in respect of the installation of the furnace are similar to those for low pressure hot water boilers Owing to the high temperature of the pipes it is important that they are kept clear of woodwork and other combustible material The London Building Act stipulates a distance of 3 in, but this requirement cannot ensure that waste matter will not accumulate around the pipes, and the Fire Offices discourage the use of high pressure hot water installations

Medium pressure hot water installations are similar in hazards and construction to high pressure hot water apparatus. The difference is that the system is sealed not hermetically but by a heavily loaded valve

Steam Heating

The appearance of a steam heating system is similar to that of a low pressure hot water system, but the pipes contain steam instead of hot water The boiler must, of course, differ because in a hot water plant it is not intended to boil the water, whereas in a steam system the water must boil continuously or there would be no steam The boiler, instead of being filled with water, is only partly filled, the upper part of the shell forming a steam dome Owing to the higher temperature produced at the boiler it is very desirable that it should be in a fire-resisting compartment or else outside the main building The hazards of steam boilers are described under "Power" on pages 110 and 111.

Steam for heating can be supplied by a boiler used only for the purpose, or by using a reducing valve from a boiler which provides steam for power purposes. Another method is to utilize "exhaust" steam, i.e. steam which has already been employed to drive a steam engine

The temperature of the piping depends on the pressure at which the steam enters it. At a pressure per sq. in. of 5 lb. the temperature is 227° F, at 25 lb it is 270° F., and at 53 lb. it is 300° F. The London Building Act requires steam pipes (other than those forming part of a system having a free "blow-off") to be at least 6 in clear of combustible material irrespective of

the temperature of the pipes The Fire Offices do not prescribe any distance, as this must, for safety, vary with the temperature of the piping, but generally no objection is raised to the pressures up to 20-25 lb per sq in. usually employed, provided the pipes are 2 in or 3 in. clear of woodwork The Fire Offices do, however, discriminate in their ratings between installations in which the steam enters the pipes at a temperature of less than 300° F. and those in which steam at a higher temperature is employed.

UNIT HEATERS

These are a fairly modern introduction used in place of or in addition to radiators They consist of a metal casing containing an electric fan and a coil of piping heated by either steam or hot water. The fan draws air around the hot coils and distributes it in the direction desired In some types steam both drives the fan and heats the air The units are generally secured to roof trusses and no special hazards attach to them.

A rather similar apparatus is heated by gas Provided they are permanently secured in positions where no woodwork (e.g roof lining) is endangered they form a suitable method of heating by gas, as the burners are out of the way of floor waste, etc

HOT AIR INSTALLATIONS

These types of heating apparatus incorporate a method of warming air by passing it over a heated surface and of distributing it to the rooms required to be warmed They vary considerably in fire hazard according to the method of heating adopted: there is little comparison between modern steam heated air conditioning plants and the fire heated types which preceded them Generally, however, the use of the term "hot air installation" is intended to imply that the source of heat is a fire heated furnace When steam coils are utilized it is more usual to refer to "steam heated air"

Fire heated hot air plants. The simplest arrangement consists of a coal or coke fired stove enclosed in a casing of cast iron rather larger than the stove Air in the space between the stove and the casing becomes warmed and as it passes out to mix with the air of the room fresh air flows in to take its place, thus providing a continuous supply of warm air. The stove itself has a flue pipe to carry away the products of combustion and to prevent them mixing with the air utilized for heating the room

A similar plant can be used for heating several rooms or a hall by placing it in the basement. Fuel is burned in an inner case and air is warmed by flowing between the inner and outer cases From this space the heated air is carried by ducts to the various

rooms, to which it is admitted by regulators There are also larger plants, in some of which the air is heated by passing through a number of tubes set in the firebox. The hot air is distributed throughout the building through ducts either by reliance on the fact that heated air rises or more generally by the use of power driven fans.

Fire hazards. The hazards at the furnace are the same as those at hot water boilers With regard to the air ducts the London Building Act provides that a pipe for conveying heated air must not be fixed nearer than 6 in to any combustible material. It will be appreciated that these ducts become very hot, and the effect on woodwork (e.g partitions, ceilings, etc) in close proximity can be judged.

These plants are unpopular with insurance companies, partly because with age the furnaces deteriorate Fires have been caused by sparks from the fire box finding their way to the air ducts via cracks or holes in the air heating tubes or the jacket surrounding the stove, and thence to the rooms of the building

Gas or oil heated hot air plants. When gas or oil burners are used in place of fire heat in the furnace there is less risk of sparks being transmitted to the air ducts, but the other hazards mentioned above exist.

Steam heated air plants utilize steam coils, around and about which air is forced by power driven fans before distribution through ducts Often air washing and conditioning plant is incorporated These plants do not have the hazards of fire heated plants, but it is important that the boiler necessary to provide the steam is safely located, and that the hot air ducts are fixed a safe distance from combustible materials

The hazards of ventilating ducts which, of course, apply also to these hot air ducts, are described in Chapter XVI.

CHAPTER XVI

VENTILATION—DRYING—FURNACES AND OVENS

VENTILATION Natural, mechanical, plenum, extraction, and localized systems—Drying, artificial, over boilers, grass and crops, enamelling ovens or stoves—Infra-red lamps—Furnaces

VENTILATION

Ventilation is the process by which stale air in buildings is removed and replaced by fresh air A comfortable, pure atmosphere promotes health, impurities, which arise from the breathing of persons in the room, from manufacturing processes, gas jets, etc., should be removed by changing the air sufficiently frequently—perhaps six times an hour is adequate

Natural ventilation. If openings are provided near the floor of a room, air enters, becomes warmed by the heat of the room, rises and passes away through openings at the top of the room. Doors, windows, skylights, lantern lights, and chimneys may provide such openings or specially designed roof ventilators may be installed Natural ventilation is often satisfactory, but in large workshops it is usually necessary to provide mechanical ventilation by the use of fans, generally, but not necessarily, driven by electric motors

Mechanical ventilation. Before describing the systems it should be pointed out that although a room may be adequately ventilated in the sense that vitiated air is replaced by fresh air, yet some portions may seem to be oppressive owing to the lack of air movement This defect can often be rectified by the introduction of *air circulating fans* of various types which do not change the air but relieve discomfort by circulating it.

Mechanical systems are of three kinds, known as extraction, plenum, and a combination of extraction and plenum

Extraction system. Vitiated air is drawn out by fans and fresh air enters at points remote from the fans. This system does not permit such control of atmospheric conditions as a plenum system does, but is effective in narrow rooms The extraction fans can be fitted in one side wall and fresh air inlets provided in the opposite side situated behind radiators or steam pipes in order that the incoming air may be warmed as it enters Fans may discharge direct to the open or ducts may be provided. When the fans are near floor level the air inlets should be at a height of 8–10 ft, but when the fans are elevated the inlets should be 3–4 ft. from the floor.

Plenum system.—Fans force fresh air into the room and the vitiated air is allowed to escape through doors, windows, and other outlets This system is suitable for any premises and is especially valuable in very large rooms where an extraction system cannot easily be applied. Because the slight positive air pressure in the room prevents leakage, cold draughts can be eliminated and the incoming air can be heated, cooled, or humidified as desired.

Plenum combined with extraction system. Fans are provided both for forcing fresh air into the room and for extracting vitiated air. A thorough changing of air in every portion of a building can be achieved by careful arrangement of the inlets and outlets Plants of this kind generally provide for *air conditioning* by means of which air is washed and humidified in a "mist" chamber containing a number of water sprayers, after which free water is removed

The air then passes through cooling or heating chambers as the case may be, and is delivered through ducts to the rooms to be ventilated, whence it is removed by other ducts

Fire hazards. The importance of immediately closing down ventilating plant when a fire is discovered cannot be over-stressed, as such a supply of fresh air would enable a fire to extend rapidly. On the other hand, ventilation intelligently carried out by those in charge of fire fighting operations is a most important aid because smoke, heat, and gases can be removed and firemen enabled to advance to the seat of the fire. Nor should it be forgotten that ventilation reduces the risk of a fire starting in many trades and processes, particularly where inflammable gases, vapours, or dust are likely to be present.

As it is possible for sparks from a neighbouring fire or chimney to be drawn into the building through the fresh air inlets, care should be exercised in selecting the position of these, and they should be protected with wire netting. Panics involving loss of life have occurred in places of amusement because smoke, not involving a fire, was drawn into the auditorium from outside sources Ducts should be constructed of brick, hollow tiles, or sheet metal and any insulating linings should be incombustible. Ducts conveying heated air must not be fixed within 6 in. of combustible materials As fire can be spread rapidly throughout a building by way of the ducts, shutters held open by fusible links might well be fitted at each inlet and outlet and at the junction of a branch with the main duct. Each point where a duct pierces a wall or floor is a weakness. It is undesirable that ducts should discharge into a roof space; they should vent to the open.

Localized exhaust ventilation. In certain situations the standard of ventilation required is much higher than that adequate

for general ventilation, e.g. in a cellulose spraying room there should be a complete change of atmosphere 30 times per hour. This is achieved by partitioning off the compartment and providing additional extraction fans In such places it is desirable that fans should discharge directly to the open or, if a trunk is unavoidable, it should be as short as possible and the fan placed at the exhaust end of the trunk

Systems for the removal of vapours, dust, and waste from grinding wheels, polishing mops, woodworking machinery and from other processes are sometimes known as "blower systems." The ducts employed are as liable to spread fires from one part of a building to another as are ventilating ducts, and if the dust conveyed is a combustible one there is the added possibility of explosion or fire in the trunks—caused perhaps by an overheated fan bearing or a spark struck by a fan. the use of non-ferrous fans obviates the latter possibility The collecting room or cyclone should be outside the building, and if canvas or fabric bags are used inquiry should be made whether the particular dust is liable to give rise to charges of static electricity on the bags or whether particles of the dust clinging to the fabric are liable to spontaneous combustion Both ducts and collectors should be frequently cleaned out (See Dust Explosions, Chapter IX)

Drying

Such a multitude of articles in so many different trades require to be dried that it is not possible to describe in detail the various methods employed. Generally, however, there is one factor in common, that the surplus moisture is absorbed by air. The higher the temperature of air the greater the amount of water it will absorb but as there is a limit to the percentage of water that even hot air will hold, it is necessary to replace the air as soon as it is saturated by further supplies of dry air Thus the most effective method of drying is by a current of hot air and it is in the means employed to provide this that drying systems differ

Natural drying consists of laying out the articles to be dried either in the open air or in a situation where there is a natural draught, e g timber is seasoned by stacking in such a manner that air can circulate all around it

Artificial drying usually takes place in a compartment sometimes spoken of as a kiln, and the degree of hazard depends on the combination of three factors—

1. *The combustibility of the articles or material being dried.* Obviously stricter precautions are required with textile articles or timber than with bricks or pottery. Any combustible material is more hazardous after drying

2 *The construction of the drying compartment* Where practicable the compartment should be fire-resisting and communicate with the main premises by a fire-resisting door. Any timber which enters into the construction of the compartment, whether floors, roofs, racks, or in any other form, becomes very dry, in which state it can easily be ignited and burns rapidly. The formation of pyrophoric carbon (see page 67) is a possibility. The hazard extends to woodwork and combustible material in the proximity of the drying room to a distance dependent on the temperature attained, e g. gas heated tunnel kilns and chamber ovens are often worked at a temperature of about 1000° C., and in these cases there should be no woodwork within about 4 ft. of the kiln or its flue.

3. *The means by which the compartment is heated.* The least hazardous methods are low pressure hot water and low pressure steam, either by piping fixed in the compartment or in the form of coils placed outside the compartment and over which air is blown by fans. The temperature which can be achieved by these methods is limited, and where higher temperatures are required high pressure hot water or steam pipes, gas burners, oil fired burners, stove heated air or coke stoves are often used. These forms of heating are described in other chapters Unless the materials being dried are non-combustible it is more hazardous for the source of heat to be in the compartment, even when adequate arrangements are made to keep the materials well clear of the source of heat, than for air heated at a separate apparatus to be blown into the room by fans, but in any event the higher the temperature the greater the hazards.

Drying over boiler. A fairly common method of drying is to construct a drying room over the boiler house in order to utilize the waste heat from the boilers. Provided the floor is of fire-resisting material and that there are no openings in it, little objection can be raised, but the fire hazard is much increased if a perforated floor is used, especially if it is not of incombustible materials such as iron or tiles.

Drying machines for grass and other crops are increasingly being used on farms Air is heated by means of a coke or oil fired furnace and then blown through the crops which have been laid on trays or otherwise stacked in a metal cased machine. The temperature of the air ranges from 100°–200° F for barley and grain to 300° F. for grass. By this process crops which might otherwise be lost owing to disease occasioned by the weather can often be saved and the risk of spontaneous combustion is reduced. The hazards turn on the light inflammable nature of the material treated inasmuch as fragments may come into contact with the furnace, or

the air passed through the crops may be too hot or may carry sparks with it (For usual hazards of coke and oil fuel, see Chapter XVIII)

Other methods of drying include—for materials suitable for each type—heating in pans or drums or conveying materials over steam heated cylinders. So many small fires are caused by drying articles in front of an open fire or around a stove that it is worth noting that many of them could have been prevented by the simple precaution of using a suitable wire guard

Enamelling ovens or stoves. Although steam heat is occasionally used, the majority are heated by gas, a temperature of about 300° F. being usually employed Apart from the general hazards of drying plants mentioned previously, there is the risk in gas ovens, whether used for enamel drying or any other purpose, of the burners being accidentally extinguished and gas thus permitted to escape and accumulate in the oven.

The Bunsen type burners are placed in rows near the floor of the stove and should be provided with shields over each row to reduce the likelihood of any of the burners accidentally being blown out The dampers fitted in the metal flues should be so designed that it is impossible to reduce the size of the flue to such an extent that the products of combustion would be unable to escape freely, as this might result in the burners becoming extinguished To prevent down draughts, which are liable to cause the burners to "light back," the flue should not be continuous, but should terminate a few feet above the stove under a hood connected to the main flue. The burner control cock and air injectors should be situated outside the oven, and if by-passes are used they should all be controlled from one tap situated near the main stop cock. To afford relief in the event of explosion the stove should be raised at least an inch from the floor.

When the vapour from the articles being dried is inflammable the ovens must be constructed with double walls, so that the products of combustion do not pass through the stove itself, but around it, on all sides, in the space between the inner and outer walls In addition to the flue carrying away the products of combustion there must be another to lead the vapour from the articles direct to the open and away from possible sources of ignition. Great care is required when drying materials which are liable to spontaneous combustion and also that no waste matter which is similarly susceptible be carelessly deposited or left in the oven.

Drying by radiant heat from infra-red lamps, particularly of painted metal articles is becoming more common because of the speed and convenience with which drying is effected Electric

lamps, similar in appearance to ordinary gasfilled lamps, are set in reflectors so arranged that the rays are concentrated on the surface to be dried Usually the articles are placed on a slow moving conveyor which passes through a tunnel commonly taking the form of an open framework supporting the lamps

The process has not been in general use long enough for the hazards to be conclusively stated, but it appears that attention should be given primarily to the ordinary hazards of the electrical equipment Owing to the loss of efficiency which would result, it is not practicable to protect the lamps with glass globes Where inflammable vapours are given off, therefore, the apparatus should be in a spacious room or thorough ventilation provided and, in order to remove the bulk of the paint solvents, before the articles reach the drying tunnel they should pass through a ventilating tunnel having an exhaust system. Other precautions require care that the articles cannot be displaced from the conveyor and, in falling, break the lamps; that the risk of articles becoming overheated is guarded against, and that the spraying or dipping process is well separated from the drying plant.

This system of drying can be used for other processes, such as removing moisture from fabrics or electrical machinery It is likely that gas heated apparatus to produce infra-red radiation will be designed.

FURNACES

The fire hazards of furnaces are similar to those of drying ovens, but as higher temperatures are attained more care is required in the location of the furnace and its flue The exact distance from woodwork for safety depends on the size and temperature of the furnace, but 4 ft. might be regarded as a reasonable minimum in many cases. Owing to the high temperature of the gases from the flue it is essential that these are not allowed to impinge on woodwork as, for example, would be the case were the flue to terminate short of the roof. When solid fuel is used, sparks are liable to be emitted and to lodge in the roof

With the increase of mass production, continuous furnaces or ovens, in which the articles or materials (e g. pottery) are entered at one end, pass through the furnace and emerge from the other end, are becoming more and more important. These furnaces are seldom extinguished, even when not in productive use.

CHAPTER XVII

POWER

WHY any form a hazard—Friction—Lubrication—Transmission—Generation—Wind and water—Boilers—Steam engines—Internal combustion engines—Electric motors and dynamos

BEFORE considering individual sources of power it is desirable to understand why the introduction of any form of power into a workshop implies increased risk In the first place the output of the factory is increased, and if the kind of work done is liable to cause fires, more work done means more hazard More waste is made and there are greater quantities of materials passing through the factory, increasing the intensity of any fire which may occur. These points have been considered more fully under the heading of "size," but an even more important factor is the risk arising from friction either at "bearings," which may be defined as the supports of moving parts of machines, or elsewhere.

FRICTION

Where two bodies rub on each other there is a force known as friction where the rubbing occurs which resists motion and manifests itself as heat. The practice of insurance abounds with examples of penalties, in the form of additional rates, imposed on account of hazards arising from friction

The following are instances of circumstances in which the underlying reason for an additional charge is frictional hazard, although the penalty is not specifically imposed as such · in respect of disintegrators or grinding machines, where there are the risks of overheated bearings due to the high speed of operation, of heat generated by the grinding process, and of frictional sparks caused by hard bodies accidentally finding their way into the machine, in the case of vertical main shafting, where considerable heat is generated at the point where horizontal shafts are taken off by means of bevel wheels, and sparking frequently occurs, in the case of millstones, where pressure increases friction, and numerous other cases in different branches of industry

The higher the speed of a particular machine the greater the friction and therefore the heat generated, but in comparing different types of machine the size of the surface over which the rubbing occurs and the class of work being done must also be considered, e g. although a sewing machine works at a very high speed the work is very light and the friction negligible compared

with a disintegrator, which may work at a slower speed but has far greater stresses imposed on it Fortunately, from a fire viewpoint, friction results in a loss of efficiency and the engineer is, for this reason, anxious to avoid it as much as practicable He therefore employs lubricants, which are introduced between the moving surfaces in order to reduce the friction and thus prevent overheating.

Lubrication

Solid lubricants, such as graphite, are sometimes used, but by far the most common are liquid or semi-liquid, consisting of hydrocarbon (mineral) oils or mixtures of mineral and vegetable or animal oils The object is to prevent the surfaces from working in contact with each other by the interposition of an unbroken film of liquid, the particles of which move more easily, thus replacing friction between the moving parts by the very much smaller fluid friction between the particles of the liquid Careful consideration must be given to selecting the most suitable lubricant having regard to the type of machine, for it must have sufficient viscosity or stickiness to avoid being squeezed out, but not so much as to retard the motion.

When the lubricant has been selected, efficient means of application must be provided, for which purpose mechanical contrivances called lubricators are used, of different types for different purposes. Some engineers of the old school maintain that no mechanical device can replace a trained mechanic using an oil can under careful supervision, but the more generally accepted opinion is that the provision of automatic lubricators reduces the risks of under-lubrication As, however, regular filling and attention is necessary the mechanic, too, must play his part, and for this reason it is highly desirable that the lubricators be in easily accessible positions. otherwise, the mechanic is liable to neglect his duty, and the omission may not be observed by the engineer until it is forced upon his attention by evidence of overheating.

Transmission of Power

Where electric motors are employed it is possible, and desirable, to supply a separate motor to each machine, thus reducing transmission risks, but where a number of machines are driven from one motor, or other power unit, it is necessary to transmit the power from the motor or engine to the machines it drives The most usual method is to employ a combination of horizontal shafts and belts, the shafts being rotated by means of a belt taken from a pulley or flywheel on the motor or engine, and belts taken

from the rotating shafting as required to drive each machine. The shafting may be "overhead," where it is always visible and easily accessible, or it may be "underground," running in pits beneath the floor, usually and preferably of concrete, but sometimes of wood There are several objections to underground shafting, the most important being that, owing to difficulty of access while machinery is running, lubrication may be neglected or done hurriedly and inefficiently, that floor waste is liable to collect in the pits, and that dust, e g sawdust, may collect on bearings, becoming caked with oil and ripe to ignite in the event of the bearing overheating In the case of overhead shafting metal trays should be hung below bearings to catch oil drippings, and the bearings regularly cleaned of combustible dust or fluff. A combination of overhead shafting and a wood ceiling or wood-lined roof is a poor one, as such light woodwork is easily ignited and any oil splashings assist the combustion Where the drive is by means of vertical shafting and the bevel gears are enclosed in wooden boxes there is the possibility of the oil-soaked wood and any light waste matter which may have accumulated in the box being ignited

Whatever form of power transmission be used the hazard arising from friction exists, especially if the shafting is not well hung, and the more machines that are driven from one unit, the more points there are at which trouble may occur Floor and wall openings necessary to convey the power throughout the building should be kept as small and few as possible, and the belt drives enclosed with non-combustible material. Where the main drive is by rope race, this should be separated from the building by brick walls, the necessary openings being as small as practicable.

Generation of Power

The generation of power implies the initiation of motion. Whether the motion be rotary, as in the case of an electric motor, or reciprocating (i e backwards and forwards), as with steam and internal combustion engines, is of small importance, as with the aid of cranks one form can easily be converted to the other.

Methods of power generation can be considered in four main classes (1) Wind and water, (2) steam engines and boilers, (3) internal combustion engines, (4) electric motors.

1. Wind and Water

There are in England a few instances of windmills still operating, the oldest working mill being at Outwood in Surrey; and pumps operated by windmill may be seen on the Norfolk Broads, but the lack of regular winds precludes their general use Water

mills are found more often, but in these days of cheap power it is doubtful how long they will remain Both wind and water mills have transmission and friction risks, but clearly there is no hazard from the source of power.

2. Steam Engines and Boilers

Boilers. The function of a boiler is to evaporate water into steam which collects in the top of the boiler, thence passing through pipes to an engine or other plant. Should the steam be further heated it is known as superheated steam and high temperatures may be attained.

Vertical boilers are used for driving small engines and cranes, or for heating tanks or presses. They are not set in brickwork and must, therefore, be lagged to conserve the heat. The firing place is at the bottom and the heat and flames pass through a vertical flue to a metal smoke pipe

Horizontal boilers are generally larger than vertical ones, and are set in brickwork, which encloses both sides, leaving only the crown to be lagged with asbestos or slag wool The firing place is at one end and the flames and heat pass through a horizontal flue or flues to a brick chimney at the other end, the flues or fire tubes being surrounded by water, which is thus evaporated to steam. A fire tube boiler, e.g a railway locomotive, has a number of flues or fire tubes In a water tube boiler the water is contained in steel tubes which pass over and through the furnace, instead of the fire tubes passing through the water.

Sometimes the water for feeding the boiler flows through a series of pipes situated between the boiler and the chimney, in order that heat which would otherwise be wasted may warm the feed water. This device is known as an *Economizer.*

Apart from the risk of explosion, which should be guarded against by the provision of pressure gauges and two safety valves (one beyond the control of the attendant), and by regular inspections, the fire hazards are due more to the location of the boiler than to any danger in the boiler itself. Undoubtedly, the best place is in a separate building, preferably a fire-resisting shed, or, failing this, in a fire-resisting compartment in a corner of the main building, having an iron door to any opening to the building.

The worst arrangement is for the boiler to be in the middle of the factory, not partitioned off in any way, surrounded with fuel, and probably waste, waiting to be burned In such a situation a small fire, of little moment in a properly constructed boiler house, might speedily involve the whole factory, and while any enclosure of non-combustible material is better than none, inasmuch as a fire is more or less shut off from inflammable material, a timber

compartment, such as is often found in old buildings, is more a hazard than a help

The flooring in front of the firing place should be of brick, stone, or concrete in order that any glowing embers which fall from the furnace shall do no damage, and it is desirable that the whole floor of the boiler house be so constructed to avoid the possibility of hot ashes, withdrawn from the furnace, being placed on a combustible floor. Vertical boilers are the chief offenders in this respect, as they are often installed in a building not originally intended to house power plant, and are placed in any odd corner; in such a case great care should be taken that wood flooring under the boiler is covered with stone at least 6 in thick, or equivalent protection provided The withdrawn ashes should be damped, placed in a metal receptacle, e.g wheelbarrow, and removed outside to a properly constructed pit or bin away from combustible material A vertical boiler usually has a metal smoke pipe, which should be carried to the open by the shortest route, care being taken to cut away combustible materials, say 6 in from the pipe, while a brick flue is an improvement it should not be carried through the building further than necessary. There must be no timber in the flue or in the boiler setting, and any woodwork, whatever, over the boiler, e g a wooden floor or timber-framed or -lined roof is a weakness, particularly if the room is not a lofty one

Sometimes drying of trade materials or of workmen's clothing is effected by placing them on the crown of the boiler, but this is a practice which cannot in any circumstances be countenanced. For other forms of drying see p. 103

Mechanical stokers of many different types are employed for supplying coal to large boilers, and where there is a steady demand for steam better results are obtained than by hand stoking. They have a little bearing on the fire risk, as the fuel can be kept further from the furnace and the boiler house clearer than where hand stoking is practised. Fuel must never be stored near enough to the boiler to be ignited by heat from the furnace. (For oil fuel and pulverized coal see Chapter XVIII.)

Steam engines. A steam engine converts the active energy stored up in the steam supplied by a boiler into mechanical work In the simplest form of engine, steam under pressure enters a cylinder through a port at one end The steam, being under pressure, tends to expand, and in doing so forces a piston to the other end of the cylinder, being then discharged through an exhaust port. Steam is then introduced at the other end of the cylinder and drives the piston back—and so on Steam is the safest form of power and, provided attention is given to the following points, no danger is to be apprehended from the engine

itself. The engine should be in a separate compartment, preferably of non-combustible materials, if the walls or floor are of timber they should be protected against oil splashings by sheet metal. Steam pipes must be well clear of woodwork or other combustible materials. Metal bins should be provided for oily wipes.

3. Internal Combustion Engines

These differ from steam engines (in which the working agent, steam, is produced by the combustion of fuel in a boiler separately, and possibly some distance from the engine) in that the motive power is obtained by the combustion of an explosive mixture of gas and air *inside* the cylinder of the engine It is in the method by which the air-gas mixture is supplied that differences arise between gas and oil or spirit engines, for in the case of the latter the oil or spirit must first be converted to gas.

The fire hazards common to all internal combustion engines are as follows, those peculiar to the different types being detailed under their separate headings.

1. *Unsuitable situation* The engine should stand in a separate room or compartment, ideally of fire-resisting construction, having iron or hardwood doors, or, failing this, constructed of incombustible materials, having doors to openings. Any woodwork liable to be splashed with oil should be protected with sheet metal Sawdust is sometimes used to soak up oil drips, but this is not a good practice and sand should be substituted Engines often stand on a raised concrete foundation, and this is to be commended as it obviates the likelihood of rags, dust, fluff, etc., collecting under the engine

2. *Hot exhaust pipe.* As the function of the exhaust pipe is to carry away the products of combustion it gets hot, and must be kept well clear of woodwork or other combustible materials. Where the floor is of concrete the exhaust pipe may be embedded in the floor, passing underground to the open; but where wooden flooring exists the best arrangement is for the pipe to pass through the nearest wall The pipe should always vent into the open and not, for example, into a chimney, even a disused one, as it is possible for unburnt gases to be delivered *via* the exhaust and to accumulate in the flue.

3. *Tube ignition.* All modern engines have magneto ignition, by which the mixture is ignited by an electric spark inside the cylinder, but some old engines have tube ignition. This comprises a metal tube kept red hot by a gas jet situated outside the cylinder, and with which the gas air mixture inside is allowed, by means of a valve, to come into contact only at the moment it is required to be ignited. These old type engines are unfortunately

found just where they are most hazardous—on farms, driving chaff cutters, where there is the possibility of chaff being ignited by the exposed flame.

4. *Oily rags.* Metal bins should be provided for the temporary reception of oily wipes, which should be removed or burnt daily.

The additional hazards of the various types are—

(*a*) **Gas engines** run on coal gas from the public mains, but some, especially in large works, on producer gas (see Chapter XVIII, Fuel).

The rubber gas bag or reservoir which is placed between the gas mains and the engine, usually against the engine-room wall, must be protected against damage by a metal shield. It must not rub against a rough (e.g. brick) wall at the back, or the friction will, in time, cause leakage.

Supply piping should be of hard metal, and most certainly not, as is sometimes found with small plants, rubber or flexible piping.

(*b*) **Oil and spirit engines** work upon the same principle as gas engines, but operations commence one stage earlier—the oil or spirit must be vaporized, and it is this operation which brings additional hazards. Oils and spirits of all grades, from petrol to heavy fuel oil, are utilized, and the engines can conveniently be considered in three groups—

(i) Spirit engines, e g petrol (ii) Medium oil engines, e g. paraffin (iii) Heavy oil engines, e g heavy petroleum.

(i) *Spirit engines.* Owing to the low flash point of the spirit adequate ventilation is necessary and there must be no naked lights in the engine room. The best situation for the fuel tank is in the base of the engine, the fuel being pumped up to the carburettor, where it is vaporized and mixed with air. In other cases the fuel tank is situated above the engine, the spirit flowing to the carburettor by gravity, where this method is employed the whole contents of the fuel tank may be discharged into the room in the event of the supply pipe becoming fractured. It is desirable, therefore, that the pipes be of metal, generally copper, that the tank be of small capacity, well secured, free from vibration or heat from the engine, and that a stop-cock be supplied immediately beneath the tank. No spirit, other than that in the feed tank, should be kept in the building, and the tank should not be filled while the engine is running The main supply of spirit should be kept outside, either in cans stored in a metal bin in the open, or in an underground tank.

(ii) *Medium oil engines.* The hazards are similar to those of spirit engines but, as the flash point of the fuel is higher, the risks are reduced.

In the case of spirit engines the fuel is so volatile that it is

vaporized by a current of cold air passing over it, but, for paraffin to be turned to vapour, heat is necessary. After the engine has been running for a short while the heat of working is sufficient to vaporize the oil For starting, and until this stage is reached, either a "vaporizer" must be warmed by means of a blow-lamp, in which event the usual hazards of pressure lamps are introduced, with the added disadvantage that the lamp, while still alight, may be set down near some combustible material, or the engine is supplied with two feed tanks, one quite small containing petrol which is used for starting and until the engine is sufficiently warm, when the supply is changed to oil from the larger tank.

(iii) *Heavy oil engines* may be similar to medium oil engines or they may be of a type specially designed for using heavy oil, known as compression-ignition engines (of which the Diesel is the best known) in which the air-gas mixture in the cylinder is fired, not by an electric spark or ignition tube, but by the heat of compression. No vaporizer is necessary as the oil is injected into the cylinder in the form of a spray operated by compressed air, and is first vaporized, then ignited, solely by heat generated through high compression in the cylinder. (Whenever a gas is compressed heat is generated and as the compression in the engines may be in the nature of 600 lb per sq. in, temperatures of over 1000° F. are attained—sufficient to ignite the oil vapour and air mixture) The engines are started on compressed air and therefore avoid the risks of starting up common to ordinary medium or heavy oil engines The general precautions for internal combustion engines should be observed.

4. Electric Motors and Dynamos

The great advantage from a fire viewpoint in the use of electric motors over other forms of power is that, by their use, transmission risks can be considerably minimized. The best arrangement is for each machine to be driven by a separate motor or, failing this, for one motor to be supplied to each small group of machines, thus obviating the floor openings, long shaftings, and many bearings which would otherwise be required From the user's point of view a breakdown of one motor throws only one machine or one group of machines out of use, whereas in factories where one large engine drives all the machinery its breakdown involves a complete stoppage of work; also, if only a few machines are required to be run at a particular time, only the few motors actually driving them are consuming current. On the other hand, there are more points at which trouble may occur, and although in the majority of cases electric motors are the most suitable form

of power, in a particular instance their appropriateness may depend on the kind of work being done.

Current from the public mains may be, and generally is, used to drive the motors, but where electric mains are not available, or for economical or other reasons are not used, electric power is generated on the premises by means of dynamos.

Dynamos. By moving a conductor across the magnetic field which exists between and around the poles of a magnet an electric current is generated. A dynamo consists essentially of a number of conductors rotating in a magnetic field, the current so generated being utilized for lighting, heating, or power purposes. The difference between a dynamo and a motor is that, whereas a dynamo converts mechanical energy into electrical energy, a motor converts electrical energy into mechanical energy. In other words the mechanical energy (e g from an internal combustion engine) used up in driving the dynamo is transformed into electrical energy in the form of current, which can then be transmitted and applied to drive an electric motor, wherein the electrical energy is transformed back into mechanical energy.

The fire hazard of electrical generation falls into two parts · first, that of the dynamo, which is similar to that of a motor and is considered later, second, and generally the greater hazard, that of the machine supplying mechanical energy, i e the engine used to drive the dynamo. Steam or internal combustion engines are generally employed, and the precautions appropriate to whichever is used must be adopted, in all cases, the generating plant should be contained in a separate compartment, and not placed where combustible materials are present or inflammable dusts can arise Care must be taken that the main switchboard is in a dry, well-ventilated position, clear of woodwork, and so arranged that rubbish or other combustible matter cannot accumulate in its vicinity.

Small generating plants, consisting of a petrol engine driving a dynamo, are often found on farms and in connection with the lighting of country mansions. In these cases hazards frequently arise due to the plant being installed in an unsafe position and/or in the charge of an unskilled man

Electric motors. Provided each motor is on a separate circuit, properly protected with fuses, and *is in a suitable situation*, the main hazard of the motor itself is that of excessive current flowing through the armature coils, causing them to overheat and ignite the insulation. such an occurrence might take place if a motor were severely overloaded, or if a short circuit were caused by foreign matter entering the motor and damaging the insulating material. It is not possible to start electric motors, other than

quite small ones, by simply turning on a switch, for if this were done excessive current would flow and damage the coils The current must be applied gradually, and for this purpose starting gear is provided, embodying a set of resistance coils which are so arranged as to allow a steadily increasing current to flow through the motor as the starting handle is moved. Surplus current, so to speak, is absorbed by the coils and shows itself as heat, with the consequence that the coils must not in any circumstances be mounted near combustible material, such as a timber partition, but should be contained in an earthed heavy metal case secured to a brick wall in a dry, well-ventilated situation.

The motor itself should be placed over a metal tray to catch any oil drippings, in a well-ventilated position, where inflammable gases cannot accumulate and where the motor is not exposed to risk of mechanical injury or to damage from water, steam, or oil, and its metal case should be earthed. Woodwork, or other combustible material sufficiently near to be ignited should fire occur at the motor, must be protected with non-ignitable material

Often the motor is enclosed in a box lined with asbestos sheeting, *and provided this is so arranged that it allows adequate ventilation* the idea is a good one, preventing any floor waste being swept against the motor. Any accumulation of fluff, dust, etc , inside the box must be regularly removed, as, otherwise, it might be ignited by a spark arising at the commutator, slip rings, or elsewhere. "Squirrel-cage" induction motors, which can be used with alternating current, are suitable for use where combustible waste is produced, as, owing to the absence of commutator and brushes, there is no sparking. Where, however, inflammable vapours or dusts are liable to be present it is essential to remove *all* possible sources of ignition, and one of two types of motor must be employed—

1. Flameproof, i.e. so designed that its enclosing case will withstand any explosion of gas within it and will prevent the transmission of sparks or flame capable of igniting gas, etc., in the surrounding atmosphere.

2 Pipe-ventilated, i e. totally enclosed in a case which is ventilated by air conveyed to and from the motor through pipes connected to the outer air.

CHAPTER XVIII

FUELS

COAL and coke—Other solid fuels—Pulverized fuel—Liquid fuel, fuel oil, creosote-pitch—Power gas producers

THE precautions necessary when boilers and furnaces are stoked with coal or coke have already been described, the coal should be stored in bunkers out of reach of heat from the furnace, and ashes withdrawn should be removed from the boiler house to a safe situation. Other solid fuels, however, are often employed from motives of economy or convenience in sawmills, sawdust and wood chips are frequently used, in other risks, also, combustible waste may be utilized. The precautions in these cases are similar to those for coal, but even greater care is necessary in storage, on account of the greater ease with which the fuel could be accidentally ignited.

It has been appreciated for very many years that, theoretically, the ideal way of firing a furnace is to introduce the fuel and air simultaneously in an intimate mixture, and the two alternatives to coal or coke of most importance and increasing use—pulverized fuel and liquid fuel—both employ this method

PULVERIZED FUEL

More than a century ago a patent was taken out for reducing coal to dust and injecting it into the furnace mixed with air. Of recent years great improvements have been made in the plant employed, with the result that it is claimed that coals which can be burned by no other means can be economically and efficiently so used.

Where only one boiler or furnace is to be fired the "unit" system is operated, consisting of a self-contained unit (situated near the furnace) which pulverizes the fuel and delivers it by means of a blower. Where there are several furnaces one unit may be provided for each, or the "central" system may be utilized by which one large pulverizer is situated some distance from the furnaces, involving the use of storage bins—either one large bin near the pulverizer or several smaller bins, one placed near each furnace. Both methods introduce hazards which will be better understood by bearing in mind that coal dust in air forms a very explosive mixture, which may be thought of as equivalent to an inflammable gas.

Air intakes should be protected against the entry of foreign matter, e g shreds of oily waste drawn into the system might cause ignition

Grinding. The coal dust in the pulverizer may be ignited by overheating due to friction, caused either by breakage of an internal part of the machine, or the accidental introduction of small pieces of metal mixed with the coal when delivered. To avoid the latter risk a magnetic separator should be provided, over which the coal must pass before entering the machine.

Leakage of coal dust from machines, pipes, etc. This can be avoided by care, but precautions should be taken so that in the event of leakage the air-dust mixture will not be ignited (See Chapter IX, Dust Explosions.) The plant should be so designed that dust will not accumulate on ledges or in pockets.

Use of coal dryers. When the plant includes a machine for drying the coal before grinding, thus increasing the efficiency of the fuel, it should be separated from grinders and storage bins—preferably placed in a fire-resisting compartment Often, however, where the unit system is operated a combined drying and grinding machine is used.

The central system has one advantage, as the grinding plant can be situated in a separate building, whereas in the unit system the grinders are in the boiler house, but this is offset by the fact that whereas the unit system delivers the fuel to the boiler immediately it has been ground the central system necessitates storage of the pulverized coal and of conveying it by compressed air from the storage bins to the burners. The product is very liable to spontaneous combustion, especially if containing any sulphur; for this reason storage bins should not be situated near any source of heat, e g. boilers, flues, hot-water or steam pipes, and where practicable the bins should be left empty when the plant ceases running.

The danger of unburnt dust in the furnace is similar to that of unburnt oil fuel described on the next page.

Liquid Fuel

The use of liquid fuel is increasing rapidly on account of the ease of storage and replacement of supplies, convenience and cleanliness in use, and the fact that it gives a steady intense heat. It is used not only for steam boilers and metallurgical furnaces, but for many other trade uses, e.g bakers' ovens, and for firing hot-water boilers supplying radiators to factories, shops, cinemas, and even private dwellings. Automatic thermostatic controls can be provided

The oil generally used, known as fuel oil, is heavy petroleum having a flash point of not less than 150° F. It is burnt in the

furnace in the form of a spray injected through special burners, at which the atomizing of the oil may be effected mechanically, by steam jet or by compressed air; in any of the methods the oil may be warmed before injection in order that it may flow and atomize more freely.

The hazard to be apprehended at the boiler itself is of a possible accumulation of unburnt gas in the furnace and flue, either through the burner becoming accidentally extinguished or by reason of the boiler being started with closed dampers, although the dampers should be constructed so that they can never be fully closed. These gases may be ignited by an incandescent object in the furnace, or by the boilerman applying a light before thoroughly clearing the furnace and flue of gas, i.e by shutting off the oil and injecting steam or air An explosion would probably result This danger is often partially guarded against by the provision of automatic controls which shut off the fuel supply as soon as the flame is extinguished.

A greater hazard lies in the storage of the oil. It is true that, as this is of high flash point, it will (as is so often pointed out by manufacturers of oil burners) extinguish a lighted torch plunged into it, because at normal temperatures it does not give off inflammable vapour. When, however, it is borne in mind that the temperature in any burning building is many times higher than the flash point of the oil so that it freely gives off inflammable vapour, and that the amount stored, even for small installations, runs into several tons, it will be appreciated that a fire occurring *from whatever cause* would be greatly intensified, extended, and rendered more difficult of extinguishment by the presence of the oil.

Storage tanks. The first precaution is so to arrange the tanks that they shall not be involved in a fire and that oil cannot escape from them to add fuel to a fire The tanks should be outside the building, preferably underground, but if this be not possible they should be situated on the lowest floor of the building in a fire-resisting tank chamber, the doorway having a raised sill to form a catch pit, having a capacity at least as great as that of the tank or tanks They should be filled from the open air through fixed piping carried down two-thirds of the depth of the tank. Where possible all piping should be underground and so arranged that oil drains back to the tank. Where elevated storage tanks are unavoidable a catch pit should be constructed beneath them of greater capacity than that of the tanks. The delivery pipe should be taken from the top of the tank, fitted with an anti-syphon valve to obviate any possibility of the tank emptying itself into the building in the event of the pipe fracturing, and provided with a stop valve immediately below the tank All storage tanks

should be supplied with indicators (not glass gauges) showing the depth of oil, should be electrically earthed, and provided with vapour vent-pipes, the upper end being in the open and turned down.

Oil supply If the storage tanks are below the level of the burners it is permissible to deliver the oil, by pump, direct from tank to burners, but where the tanks are elevated a direct gravity flow is to be avoided, as, in the event of fire breaking out in the building, it might not be remembered to shut off the supply, or indeed it might not be possible to do so, with the result that the entire contents of the tanks would flow into the building and feed the fire. In either case it is more usual to provide, inside the building, a small service tank from which the oil flows to the burners and which is replenished as required from the storage tank. This service tank must be placed so that escaping oil cannot reach any heated surface and must have an overflow pipe leading either back to the storage tanks or to a safe place in the open to guard against overfilling.

Fire valves. Outlet pipes from all tanks should each be fitted with a fire valve (self-closing in the event of fire) placed as close to the tank as possible and operated by the breaking of fusible links placed over each firing place. Apart from the time saved by automatic fire valves it must be appreciated that in the event of fire it may not be possible even to approach manually operated valves to cut off the oil supply.

Creosote-pitch. When, instead of fuel oil, a mixture of creosote and pitch is used, it is necessary to keep the mixture in a liquid state by maintaining in the storage tanks and the supply piping a temperature of about 90° F. and to increase the temperature to about 200° F. near the burners in order that proper atomization may be obtained The precautions for oil fuel installations should be followed as far as they are applicable, but there are a number of other points which must be observed.

The necessary heating should be applied in the tanks by steam coils or electric immersion heaters or by heating the tank chamber itself by steam or hot-water pipes or electric tubular heaters. Any lighting should be electric and the usual precautions where inflammable vapours are likely should be followed. The oil in the ring main should be kept warm and the temperature increased near the burners by fitting steam pipes or electrical pipe heating cables—in all cases thermostatic control is desirable. Any other forms of heating the oil are most unsuitable. All insulation for tanks, pipe lines, etc , should be fire-resisting. When coal gas is available, a pilot jet near the burners should always be kept alight when the burners are in operation in order immediately

to relight them in the event of their accidental extinguishment. Provision should be made for draining the whole system, for drawing off water from the surface of oil in tanks, and for oil pumps to have a safety relief valve fitted across the delivery and suction connections.

Sometimes pitch alone is used, and where this is the case the precautions should be applied as far as possible.

Power Gas Producers

Although, in towns, most gas engines draw their supply from the public gas mains, yet, in connection with large plants, especially those installed in factories where quantities of wood waste are made, it may be economical to manufacture power gas on the premises, and in some country districts where no gas mains exist there is no alternative to doing so.

When steam is blown through red-hot coal or coke, an inflammable odourless gas known as water gas is produced, being a mixture of carbon monoxide and hydrogen, or, if air instead of steam be passed over the red-hot fuel, producer gas, a mixture of carbon monoxide and nitrogen, is generated. Either gas is suitable as a substitute for coal gas in running gas engines, as is also the combination of the two obtained by passing both air and steam through the red-hot fuel.

The plants in use fall into two main groups—

1. **Suction gas producer plants,** through which air and/or steam is *drawn* by the suction exerted by the engine on the first stroke of its cycle of operations. The gas is thus delivered directly to the cylinder of the engine and no gas holder is necessary.

2. **Pressure gas producer plants,** through which the steam and/or air is *forced* and the gas collected in a gas holder. These are larger plants intended for supplying a number of engines, and are not found so frequently as suction plants.

The fire hazards are similar in each case, and a description of the more common suction plant will serve also as a guide to the operations of pressure plants, in connection with which, however, there is an additional hazard in respect of leakage from the gas holder.

Suction gas producer plants consist of two main parts—the gas generator and the scrubber. The generator resembles in appearance a vertical boiler with a hopper on top through which the fuel is fed. Water, introduced at the bottom, turns to steam, and is drawn, with hot air, upwards through the red-hot mass of fuel The gas so produced is drawn off at the top through a pipe leading to the scrubber, which is a vertical cylinder filled with coke kept wet by a spray of cold water. In passing through the

scrubber the gas is cooled and relieved of impurities, and is then drawn into the engine *via* an expansion box. The necessary suction is provided by the running of the engine, but, as the engine cannot run until gas from the producer plant is supplied, some means must be provided of commencing the generation of gas without the aid of the engine In starting up, the fuel in the body of the generator is lit and a fan is operated by hand to provide a draught (taking the place of the suction provided by the engine when running) At first the gas produced is not of suitable quality, and is allowed to escape through a waste pipe, which must vent to the open, but after a few minutes the gas is tested by the application of a flame to a test cock and, if satisfactory, is allowed to pass to the engine, the waste pipe being then shut off. As soon as the engine commences to work the fan may be stopped, but it must continue to run up to this moment, as otherwise the flame at the testing cock might be drawn back into the piping, causing an explosion of the gas contained in the scrubber

These plants should be situated in the open or, if desired, under a light roof of incombustible construction, in order that any gas leakage may be dissipated in the open air If they must be inside a building they should be shut off in a well-ventilated, fire-resisting compartment. The platform, which is usually erected around the plant to facilitate the supplying of fuel to the hopper at the top of the generator, should be of metal and have no fuel or other combustible material stored on it. The flooring, too, should be incombustible to obviate danger from any hot ashes falling or being placed on it. The greatest risk probably arises when the scrubber is cleaned out, and before this is done the plant must be stopped for some hours and the fan worked to blow out through the waste pipe all gas remaining in the system. The foul coke contains an accumulation of gas and it is important that no naked light is near while it is being removed previous to filling the scrubber with fresh coke When the plant is standing idle the waste cock should be left open, and before attempting to light the fire any residual gas must be removed by means of the blower fan.

CHAPTER XIX

SOME ELECTRICITY HAZARDS

STATIC electricity how arising and safeguards—Dry-cleaning—Lightning. lightning conductors—Accumulator charging arrangements and precautions—Oil-cooled transformers

STATIC ELECTRICITY

EVERY child has found by experiment that stroking a cat backwards in the dark produces two phenomena—first a crackling sound is heard and sparks are seen, second the cat protests both with its voice and with its claws The second is of temporary interest only, but the first is of importance, inasmuch as it is the child's introduction to static electricity

Static charges result from the close contact and subsequent separation, generally brought about by friction, of dissimilar materials, whether they are solids, liquids, or gases. Charges can be generated on the surface of both conducting and non-conducting substances On a conducting substance the charge will spread rapidly over the surface, and if this is earthed at any point the charge will be quickly and safely removed On a non-conductive substance the charge will spread slowly, if at all, and effective earthing will be more difficult as only the portion or portions in contact with the earthing device will be affected by it. Should a charge be generated more quickly than it can be discharged it will accumulate on the substance. An electrified body tends to lose its electricity by sparking towards other bodies near it, and, owing to the high temperature of an electric spark, any inflammable vapours or dust clouds in the vicinity may easily be ignited.

Precautions take the forms of humidifying the air, thus tending to prevent the generation of charges, and of effectively earthing machinery and substances likely to be affected, thus safely conducting away the charges. The following are a few examples of the different ways in which static electricity can be generated in industrial operations

Friction of belts against pulleys, of grain against a wooden shute, or of rolls of paper against heated drums, as on paper-making machines or rotary printing machines In these cases earthed metal combs, or copper wire can be placed in contact with the belt or paper, immediately after the place where the charge is generated. In the cases of cotton fabric, paper, etc., moving over cylinders the charges can be neutralized by passing the

material through a high voltage alternating electric field, which must be so arranged that it will not itself provide a source of ignition. Care is needed in connection with photogravure (intaglio) printing machines as the inks give off inflammable vapours—ample ventilation, too, must be provided

At rubber-coating machines highly inflammable vapours are given off. similar precautions are necessary and the air should be humidified

In dust clouds, by friction with the air. The best safeguard is to humidify the air, as charges are not formed so readily in a damp atmosphere and are more quickly dissipated, but where this is not possible all machinery, pulleys, etc., should be earthed.

Filling of tanks with petrol from tank wagons. Charges are formed both in the tanks and on the liquids The necessary precautions include earthing of both the tanks and wagons and the provision of a filling pipe, either entirely of metal or having an internal lining of coiled wire, in either case electrically-connected to both the wagon and the tank.

Dry-cleaning. Benzene, which is the liquid most commonly employed in dry-cleaning works, is a bad conductor of electricity, and when textile articles are moved about in it, or rubbed with it, they become electrically charged. Should a spark be thus caused the mixture of benzene vapour and air is likely to ignite and cause an explosion The conductivity of benzene can be improved by the addition of special soaps containing water, and another precaution is the provision of humidifiers (jets of steam or water) in order to keep the air in a damp state. Washing machines should be earthed and have self-closing, airtight lids, they should be allowed to stand for several minutes after working before being opened, in order to allow the static charge to leak away to earth

In such works the ordinary precautions adopted where inflammable vapours are present—free ventilation and the avoidance of any possible source of ignition—must be observed in addition to the special precautions against static charges If a solvent of relatively high flash point, e g. white spirit (about 80°–100° F.), is used the hazard is considerably reduced

When dry-cleaning is undertaken at home, petrol is generally used and numerous deaths have occurred, sometimes through rubbing articles, particularly silk, and thus producing static charges, but more usually through the vapour drifting, perhaps a considerable distance, to a flame The dry-cleaning machines seen in shop windows do not employ inflammable solvents, but use either trichlorethylene or carbon tetrachloride, both non-combustible, although inimical to health. Cases have arisen, however, where, despite warnings, the shopkeeper, either by

reason of running short of the solvent supplied by the manufacturers of the plant, or of desiring to purchase a cheaper solvent, has adulterated with petrol the cleaning agent supplied. The danger of such a procedure is very great, as the machines are not designed for use with inflammable solvents, and further it is likely that such a shop would contain various possible sources of ignition

LIGHTNING

In 1751 Franklin demonstrated the identity of lightning with an electric spark by tapping a thundercloud of some of its electricity by means of a kite, but in spite of this and of much more recently acquired knowledge, the behaviour of lightning is not completely comprehended

The electricity in a thundercloud is generated by friction of warm air passing over the earth's surface and then rising, of the water vapour in the air condensing into raindrop, and of the drops breaking up into others A difference of electrical potential is thus established in the atmosphere, either between neighbouring clouds, or between a cloud and the earth. The intervening air acts as an insulator, but, in time, the difference in potential may become so great that the air is unable to support the stress, with the result that a large spark discharge takes place in the form of one or more lightning flashes. When the discharge occurs from cloud to earth it takes the line of least resistance, and as air is a poor conductor of electricity the discharge chooses the easier method of descent by way of any better conductor that is in the vicinity Such conductor may be a church spire, a building in a high and isolated situation, a weather vane, or other projecting object.

Lightning conductors. A lightning conductor serves a useful purpose in providing an easy path for a lightning flash, thus protecting surrounding property from damage which might otherwise occur by reason of the discharge passing through it on its way to earth It has been suggested that a lightning conductor, by relieving the electric pressure between a cloud and the earth, serves the additional purpose of preventing a flash from occurring at all, but it is very doubtful whether this is true.

Rods should be of non-rusting metal, generally copper, sufficiently thick to conduct any discharge without melting, and fixed to the building vertically, projecting above the highest parts. The bottom end should be earthed to a metal plate sunk in the ground sufficiently far to be always moist, and where this is not practicable a quantity of metal should be buried with the plate, the earthing should not be near a gas main Every portion and

projection of the building must be protected, as a guide to the numbers necessary, it may be assumed that a rod will protect a cone-shaped area having its apex at the top of the rod, the radius of the circle at its base being two to four times the height of the rod

Apprehension sometimes exists that the use of wireless-receiving aerials attracts lightning, but it is probable that *provided the "aerial" is connected to the "earth"* when the set is not in use, the aerial acts as a lightning conductor and is a protection rather than a hazard If, however, the aerial is not so earthed a lightning flash might easily burn out the set, and possibly cause a fire A lightning arrestor, which should always be used with an outside aerial, consists of a thick earthed wire placed outside the building, leaving a narrow gap between itself and the aerial. The "wireless" current has not sufficient pressure to jump this gap and follows the aerial into the building, but a lightning flash easily jumps the gap and is safely conducted to earth

ACCUMULATOR CHARGING

Since accumulators do not generate but merely store electricity, it follows that they require recharging at intervals when the original store has been exhausted The cases of motor-car batteries are usually of a moulded hard rubber composition which is not easily ignited, but, while many radio batteries have heavy glass containers, a fairly large proportion are constructed of celluloid It is largely the use of celluloid which renders the process of charging hazardous, but fortunately celluloid cases are becoming less common

Most motor garages and radio dealers undertake to charge accumulators, and it is usual to find, at a charging station, accumulators of all sizes and types, some of which almost certainly have celluloid cases The charging arrangements can be considered in two parts 1 The supply of current. 2. The position and arrangement of batteries.

1. **Supply of current.** Direct current is necessary, where the supply is alternating current it must be transformed to direct current before charging can proceed

(*a*) Where no public mains exist the current must be generated on the premises and the usual precautions, detailed in Chapter XVII should be applied

(*b*) Where direct current mains are available, connection is taken from them, and electric lamps or wire coils are used as resistances, i e to take up any surplus current In such cases "series" charging is always adopted

(c) Where alternating-current mains exist the current may be transformed to direct current in one of two ways—

1 By means of a motor generator set, in which an A.C. electric motor driven from the mains is coupled to a D C. generator. In such cases an automatic battery cut-out must be provided

2 Valve type rectifiers, in which the current is converted by the action of a valve (similar to the rectifier valve in an all-mains radio set) This is a very much safer method, if the plant is by a reputable maker, e g Davenset, Tungar, etc.

2. Position and arrangement of batteries. The potential required for charging is about 3 volts per cell, e g a 6 cell (12 volt) accumulator requires a potential of 18 volts. *Parallel charging* is the safest method, as each battery is on a separate circuit and only a low voltage is needed. *Series charging* consists of connecting a number of batteries in series in one circuit If there are 70 cells in the circuit and the first and last batteries are placed adjacent to one another the difference of potential between them is over 200 volts and the likelihood of leakage much greater than if the positive and negative leads were placed at opposite ends of the bench when the difference between any two cells would only be 3 volts. Current leakages occur via the damp sides of accumulators and across damp, or otherwise conducting, benches.

Fire hazards. Hydrogen is given off while batteries are being charged, particularly if they are charged at too high a rate Ample ventilation must, therefore, be provided, and care taken to avoid sparks or arcs which might ignite the gas These can be caused by the leakage of current from one accumulator to another, by the use of corroded wiring, broken connecting wires, or loose terminals Internal short circuits may give rise to sufficient heat to ignite a celluloid case of an old accumulator.

Precautions. The accumulators should stand on a non-conducting, non-porous, non-combustible surface, e g plate glass, glazed tiles, or slate, so spaced that they are at least 1 in. apart. Combustible material near to, or within 6 ft above, the bench should be protected with asbestos sheeting As much of the wiring as possible should be permanent and proper terminals supplied. Resistance coils should not be near combustible material, nor where hot fragments could fall from them on to accumulators Accumulators should not be left on charge unattended and a bucket of sand or a C T C extinguisher should be provided.

The greatest safeguard is for the charging plant to be in the constant charge of a careful, competent attendant, who will see that accumulators are in a fit condition for charging and will avoid charging a series at a rate higher than that suitable for

the smallest cell. It is probable that more fires are caused by inexperienced and slipshod handling than by any other cause

OIL-COOLED TRANSFORMERS.

High tension electric power transmission has necessitated the installation of oil-cooled transformers in many factories Fires have occurred due to the oil becoming ignited through over-heating of the transformer, and in some cases burning oil has overflowed It is desirable that such transformers should be situated outside the main buildings or, if this is not practicable, in a separate fire-resisting compartment; in either case so arranged either by the provision of sumps filled with pebbles beneath the transformer or by the use of dwarf walls, that any escaping oil cannot gain access to the main buildings. Carbon dioxide or carbon tetrachloride may be used for extinguishing fires in these or other oil-filled electrical apparatus Many transformer, etc , chambers have automatic carbon dioxide installations with fixed piping, others have water spray equipment. Provided the current can be shut off, a fire may be dealt with in a similar manner to any other oil fire

CHAPTER XX

SOME MISCELLANEOUS HAZARDS

SILENT risks—Empty buildings—Buildings in course of erection—Pavement lights and gratings—Refrigerators—Smoke holes—Banana-ripening rooms—Melting—Welding· Electric, oxy-acetylene, liquid oxygen plants—Soldering and brazing—Light metals. magnesium, aluminium—Housing of vehicles—Runabout trucks—Decorations—Hazardous trades

SILENT RISKS AND EMPTY BUILDINGS

A MANUFACTURING risk is said to be "silent" when the machinery and plant remain in the building but are not worked. An "empty" building, of course, is devoid of all contents.

The hazards in connection with empty buildings depend largely upon the condition in which they have been left by the previous tenants It is not unusual to find the premises littered with rubbish, trade waste, unwanted wooden fittings, and other combustible matter, which should be removed at the earliest opportunity. Any broken windows or gratings should be made secure, either by replacing glass or covering the opening with sheet metal, to prevent any malicious or careless persons from dropping or throwing in such articles as glowing cigarette-ends or lighted matches, and to obviate the possibility of sparks finding their way into the building. In rough neighbourhoods it may be desirable to protect windows against missiles with wire netting

The premises should be securely locked to prevent the entrance of undesirable visitors; tramps frequently make use of empty buildings and, even if they do not light fires for warmth or cooking purposes, are liable to be careless in the disposal of cigarette-ends, etc. Electric and gas supplies should be shut off at the mains, but sprinkler or fire-alarm installations should be maintained in good order

The same precautions should be taken with silent risks, but in this case the additional question of moral hazard arises. The fact of a risk being "silent" may imply an unsuccessful business: it may be the result of bankruptcy, inability to meet financial obligations, or other unsatisfactory features. In such circumstances the buildings, plant, or stock may well be a potential liability to the owner instead of an asset, and a fire might react to his advantage by ridding him of an encumbrance

Arrangements are often made for the occasional lighting up of boilers, etc , to keep them in good condition, and in spite of the possibility of a fire being so originated it is probably a good

practice, as it indicates that the owners still take an active interest in the preservation of the property The employment of a reliable watchman is a good general safeguard

Buildings in Course of Erection or Demolition

Buildings in course of erection are not, as a rule, very heavy risks, and as a night watchman is almost invariably employed, chiefly to prevent pilferage, an outbreak of fire is generally observed soon after its inception.

Concrete mixers and circular saws are driven by portable petrol engines, with the risks attendant upon the working of the engine and the storage of petrol A quantity of shavings is made, due to the large amount of woodworking necessary, while stocks of timber, paints, etc , provide combustible material. Wooden scaffolding and staging is still generally employed, although it is now practicable to use metal scaffolding , tarpaulins and canvas screens are often used to protect unfinished work Temporary forms of heating are required for warming glue, tar, solder, etc , for the comfort of employees and the preparation of their meals These usually take the form of "primus" stoves, cokels, and open fires Acetylene or other flares are sometimes used for lighting purposes Acetylene may be used for welding, and blow-lamps for various jobs.

Where structural alterations are made to an existing building some of the above described hazards exist, varying according to the nature of the alterations The hazards are rather more serious when the building is in occupation on account of the additional combustible contents present

The risks of buildings in course of demolition are somewhat similar to those of buildings in course of erection, but probably less care is exercised by the contractors and their workmen. Acetylene generating plants, with their attendant hazards, are much used in connection with cutting of metal, and a spark might easily ignite accumulations of demolished woodwork

Pavement Lights and Gratings

Cellar gratings at pavement level permit careless passers-by to drop glowing cigarette-ends or matches into the cellar. Small courts in front of cellars, sometimes known as "areas" (not to be confused with the areas mentioned in Chapter V), are often covered with pavement gratings and are liable to become depositories for rubbish. If the gratings are not required for light or air they can be covered on the underside with sheet metal , otherwise fine mesh wire netting or expanded metal should be fixed there and the space under kept clear of combustible materials. For the

same reasons broken pavement lights should be repaired and cellar flaps, used for the reception of goods, kept closed when not in actual use

REFRIGERATORS

Small refrigerating plants are being increasingly used in butchers', fishmongers', and other food shops, and in private houses, hotels, etc., while large plants are installed in many wholesale trade premises. Most small refrigerators depend on the principle that when a liquid passes into a gaseous state heat is absorbed, and those in use can be divided into two kinds · those employing compression and those relying on absorption of gas.

Fire may originate at the electric motor, or other form of power used, or by reason of the pipe leading to the condensing coils becoming so hot as to char woodwork or other combustible material in contact with it. Fire hazards may also arise from the accidental escape of the refrigerant employed, should it be either inflammable, e g methyl chloride, or of a nature likely to hamper efforts at fire extinguishment, e g. ammonia

SMOKE HOLES FOR FISH, BACON, ETC

The usual type of smoke hole found in retail fishmongers' shops consists of a timber structure built over a brick well in which smouldering sawdust is contained. The well should be of sufficient depth to ensure that the burning sawdust cannot come into contact with the timber walls which, in the course of time, becoming dried out and covered with a sooty, greasy deposit, are easily ignited. The objectionable practice of burning up empty wood boxes in the smoke hole should be prohibited Where the walls are of metal or brick the risk is minimized, but in any case it is desirable that the smoke hole be situated outside the main buildings

BANANA-RIPENING ROOMS

These are almost invariably timber-partitioned-off compartments, kept at a steady temperature of about 60° F. by means of gas jets. The burners should be enclosed with wire guards in order to prevent any loose straw used for packing from coming into contact with the flame, and should be fixed a safe distance—say 12 in —from the timber partitions. Another method of fruit-ripening involves the use of a weak mixture of ethylene (an inflammable gas) and air—in this case care must be taken that no naked lights or other source of ignition are present Carbon dioxide is sometimes used, but this is a non-inflammable gas

Melting

Heat is used for melting solid substances, e g fats, waxes, tar, sugar, glue, etc., in a vast number of trades, and the appliances used are too numerous for individual mention. The crudest method consists of placing the substance to be melted in a vessel which is then heated by the direct application of heat from either a fire or a gas-ring. Considerable risk of boiling over arises, especially if the pan be carelessly filled above the customary level, and, if the material be of a combustible nature, its ignition is almost certain This method is not at any time desirable, but the risks can be minimized by so securing the apparatus that it cannot be upset, by turning in the rim of the vessel to reduce the probability of boiling over and by so arranging the apparatus that any overflow cannot come into contact with the flames.

The safest method is to use steam-jacketed pans (the vessel containing the material being melted is enclosed with a "jacket" supplied with steam from the works' boiler), which not only reduce the probability of a "boil over" but avoid the danger of ignition in the event of such an occurrence Where steam is not available water-jacketed pans are a good substitute, though arrangements must be made to prevent any overflow from coming into contact with gas-rings or other appliances used for heating the water Wood floors under all kinds of melting appliances should be suitably protected Where hot oil jacketed plant is used steady temperatures can be maintained and the only objection seems to be the possibility of oil leakage due to pipes fracturing in a fire.

Fish-fryers' shops often have fire-heated pans, though gas heating is becoming more common, and it is not unusual for the boiling oil to ignite. These stoves should stand on a concrete floor and be supplied with a brick flue of suitable thickness—many fires have occurred because a frying stove has been installed in a shop having a flue intended only for ordinary fires Woodwork is generally saturated with oil and such shops form heavy risks.

Somewhat similar conditions may arise in canteen and other kitchens Apart from the risks of fats boiling over probably the chief danger is the accumulation of fats, etc , in ventitating hoods and trunks, which should always vent to the open and be at least 9 in. clear of woodwork.

Welding

Welding, which is the process of uniting metals by fusing them together when they are in a plastic condition brought about by heating, is practised by metal workers, motor vehicle repairers, and others. The very high temperature necessary is attained

either by the use of an oxy-acetylene blow pipe flame or by electrical welding plant. Neither should be used where inflammable gases, vapours, or dusts are liable to be present.

Oxy-acetylene blow pipes are used both for welding purposes and for cutting metals. It is generally appreciated that as the flame is such a hot one it must not come into contact with combustible materials, but sufficient care is not always taken to prevent hot pieces of metal and molten slag from dropping on to combustible material. when work takes place over a wood floor a tray should be placed beneath the work. Hot sparks are thrown some distance, and if there is a possibility of their alighting on ignitable matter metal screens should be used to confine such sparks

When small quantities of the gases are required intermittently the supply is usually from cylinders, but in places where large volumes of gases are necessary an acetylene generator (see pages 82–85) is installed and possibly also a liquid oxygen plant.

The gases are led to the blowpipe through stout reinforced canvas hoses. Should the blowpipe nozzle become obstructed, the oxygen, which is under a greater pressure than the acetylene, may flow into the acetylene pipe and communicate ignition back to the generator, if such is the source of supply, causing an explosion. The nozzle must, therefore, be kept clean and any particles of slag metal, etc, removed. To obviate the possibility of any "flashback" or "backfire" reaching the generator, a hydraulic back pressure valve must be fitted in the acetylene supply line as near as possible to *each* blow pipe. Such a valve permits acetylene gas to flow *towards* the blow pipe through a water chamber, but gas endeavouring to force its way *from* the blowpipe to the generator is checked by the water and escapes to the open.

When the acetylene gas is obtained not from a generator, but from a cylinder of dissolved acetylene, hydraulic valves are not necessary, but an automatic pressure regulator or reducing valve must be employed.

Care of cylinders of gases. The risk of explosion is less when the acetylene is supplied from cylinders than when a generator is used. The cylinders of dissolved acetylene must not be kept in hot places nor should they be roughly handled or dropped. Leakage from fittings is to be avoided. Cylinders of compressed oxygen demand similar care. It should be noted that oil or grease must not be used on valves or fittings, as they are liable to ignite spontaneously in the presence of oxygen. Any leakage of oxygen would intensify a fire already burning

Liquid oxygen plants are not found so often as acetylene

generators. Even large users of oxygen generally obtain the gas in cylinders When, however, a liquid oxygen plant is installed the precautions necessary are to avoid leakage of the gas, which would greatly assist any fire, to ensure that no oil is used on valves and that no combustible material is near the plant

Electric welding. Provided the usual electrical safeguards are observed, the only hazards arise from the possibility of flying sparks or molten metal igniting combustible materials Metal shields should, therefore, be placed around the plant and any wood flooring adequately protected. The work must not be done where inflammable atmospheres are likely

Soldering and Brazing

In these processes the surfaces to be joined are heated (but not to such an extent as to render them plastic as in welding) and united by the application of an alloy, which adheres to, or interfuses with, the metals to be joined

Soldering is performed with a heated iron, and the fire hazards lie in the methods employed in heating the iron. Soldering stoves, whether heated by gas or by solid fuel, should stand on a heavy metal tray, well above the bench, or on a 2-in thick stone slab—a sheet metal covering to a wooden bench is not sufficient to prevent the bench becoming charred Rests should be provided in order that the hot iron, when not in use, shall not be laid down against combustible material

Brazing, or hard soldering as it is sometimes termed, produces a stronger joint The parts to be joined are heated in a furnace, forge or, if small enough, by a gas blow-pipe or a blow-lamp Forges are usually fuelled with coke, and a draught is supplied either by bellows or by an electrically-driven fan Care should be taken that there is no combustible matter near the forge or its flue, and a hood should be supplied to catch sparks Gas blow-pipes use coal gas from the public mains, and sometimes an oxy-coal gas flame is used, in which case the oxygen is obtained from cylinders. There should be no combustible material near the work upon which the flame could impinge, and here again a sheet-metal covering is not sufficient protection to a wooden bench

Blow-lamps burn mineral oil or spirit under pressure, and the general risks of the filling, lighting up, and use of vaporizing lamps exist An additional hazard of blow-lamps is that they are liable temporarily to be put aside while still alight, and may ignite combustible matter near which they have been placed Blow-lamps are used not only for soldering purposes, but by painters for removing old paint, and by plumbers, who also extensively use "Primus" type stoves

LIGHT METALS

This term includes aluminium and magnesium and their alloys, which are much used when lightness combined with strength is required

Magnesium alloys (elektron is a prominent example) when in the mass, such as ingots or castings, are very difficult to ignite, but when finely divided in the form of turnings, swarf, or dust they will burn fiercely Such forms can be ignited by friction during machining or by sparks

Precautions include keeping the machine and floor clean and dry, not allowing turnings to accumulate, but placing them in a metal bin with a lid, keeping tools very sharp and taking heavy cuts to avoid friction and the production of fine turnings, avoidance of tool grinding operations which produce sparks The dust is especially hazardous and will form explosive mixtures with air. Grinding of magnesium or its alloys should be performed only in detached sheds and special precautions taken.

Should a fire occur, water must not be applied, as hydrogen would be liberated and the fire would be intensified Soda acid, foam, C.T.C, and methyl bromide extinguishers are all similarly unsuitable Powdered asbestos, asbestos-graphite (80 per cent dry asbestos fibre, 20 per cent graphite) or, less satisfactorily, dry sand should be gently applied so as to cover and smother the fire but not disturb the burning material Small fires can often be smothered with an asbestos hand cloth. It has been suggested that magnesium swarf fires can be extinguished by the application of heavy oils, but their use is undesirable owing to the possibility of the oils becoming ignited and of danger to the operator.

Aluminium and its alloys can be regarded as non-hazardous, except in the form of dust clouds when precautions must be taken against ignition. There are two processes associated with some aluminium alloys, e g duralumin, which are of interest.

Heat treatment. The alloys can, by heat treatment, be softened, in which state they are easy to work, but have the property of regaining hardness after a few hours The heat treatment consists of immersing the metal in a "salt bath," which is a steel tank containing a mixture of potassium nitrate and sodium nitrate heated to 400°–500° C, at which temperature the mixture is liquid. The salts are not inflammable but evolve oxygen when heated The bath may be heated by fire, oil or electricity, but usually thermostatically controlled gas jets are used. If, due to overheating, the salts decompose and react with the metal of the bath, or if wet or greasy articles are dipped, there is the possibility of an explosion, which would scatter molten salts

over a wide area, causing ignition of oxidizable matter with which they came into contact.

The baths should not be situated near combustible materials nor over a wooden floor but placed on brickwork or concrete and surrounded by a dwarf wall in order to confine any leakage.

Anodic treatment protects the surface of duralumin against corrosion It is rather similar to a plating process and necessitates the use of an electric motor generator to supply low voltage current to a bath warmed by gas or electricity.

Housing of Vehicles

Most businesses maintain some form of transport for their goods, and the vehicles can be considered in three classes.

Horse-drawn vehicles. The hazards lie in the fodder and litter necessary for the horses Hay and straw are usually kept in a loft over the stable, and care should be taken that the lighting arrangements are safe

Steam-driven vehicles necessarily embody a fire-box, from which hot cinders may fall, and although a metal tray is provided to catch the ashes it is undesirable that the floor be of wood. All steam vehicles should be supplied with spark arrestors and, if the walls and roof of the standing and loading places are not of incombustible material, they should be lined with sheet metal or asbestos cement sheeting.

Petrol-driven vehicles. Wood floors are objectionable, as they are likely to become impregnated with petrol and oil drippings. Fuel tanks of vehicles must not be filled in the garage, and no petrol should be allowed in the building other than that in the tanks of the vehicles. (For lighting and heating arrangements see pages 68 and 95)

When more than one class of vehicle is used separate accommodation should be provided for each, e.g. the fireboxes of steam vehicles are objectionable where petrol vapour or inflammable materials, such as hay or straw, are liable to be present.

Runabout Trucks and Cranes

In many factories and warehouses, mechanically propelled runabout trucks are used, some being driven by electricity, but the majority by petrol engines The precautions to be observed centre around the fuel tank, which should be of superior construction, securely and permanently attached to the vehicle, and of sufficient capacity to contain a full day's supply of fuel in order that frequent filling may be obviated. The tanks need then be filled only at the beginning of each day, but this operation must not be performed inside the building. The exhaust pipe must be

provided with a device to prevent the emission of sparks and flame, and the induction pipe so designed as to preclude the possibility of "flash-backs." A drip tray should be fitted to prevent oil dripping on to the floor.

Decorations and Theatrical Effects

When rooms are decorated with paper hangings, carnival novelties, celluloid articles, cotton wool, and other fancy goods, fires often occur. Christmas trees and holly, too, are easily ignited when they are dry It is obvious that candles should not be used in conjunction with such materials, but it is not always realized that electric fairy lamps, which are usually strung up on poor quality flexible cords and fittings, involve any risk. Decorations in contact with these or with ordinary lighting bulbs may be ignited, especially if the lamps are partly enclosed in, say, cotton wool so that ventilation is impeded. Such decorations may fall into open fires or on to stoves or be ignited by still-glowing discarded matches or cigarette ends.

Theatrical performances in village halls, etc, involve the use of scenic effects, flimsy draperies and dresses. A useful precaution is to provide a blanket on the stage and in each dressing room. No celluloid films should be used in such halls.

Hazardous Trades

The following are examples of hazardous trades—

Acetylene welders, aircraft factories, artificial silk manufacturers, bakeries (steam), basket makers, bedding manufacturers, boot and shoe factories, brush makers, cardboard box makers, cellulose paint manufacturers and sprayers, celluloid dealers and workers, clothing factories, coffee roasters, confectionery and jam factories, cork cutters, corn mills, cotton mills, curriers, chemists (manufacturing), distillers, dry cleaners, film dealers, firework and firelighter makers, flax, hemp and jute mills, floor and shoe polish makers, french polishers, furriers, hat makers, hay and straw dealers, insecticide and fumigant makers, japanners, lace manufacturers, leathercloth manufacturers, laundries, linoleum makers, match manufacturers, motor body builders, oil and colourmen, oil refiners and dealers, paint makers, paper mills, printers and envelope makers, rag and waste dealers, rope makers, rubber dealers and manufacturers, sail makers, saw mills, ships chandlers, spice grinders, sugar refiners, tanners, tar distillers, tarpaulin and oiled silk makers, toy factories, upholsterers, wallpaper makers and dealers, waterproofers and waterproof garment makers, woollen mills, woodworkers of all kinds

CHAPTER XXI

HAZARDOUS GOODS

CHARACTERISTICS—Storage—Alphabetical list of hazardous goods

CHARACTERISTICS OF HAZARDOUS GOODS

IN estimating the fire hazards of a particular substance or class of goods, three main factors must receive consideration—

1. The risk of the goods originating a fire
2. The risk of them spreading a fire already started.
3. Their susceptibility to damage.

1. **Originating risk** includes liability to—

(*a*) Ignite and burn easily—inflammability, e g. celluloid.

(*b*) Give off inflammable vapours—volatility, e g. petrol

(*c*) Spontaneous combustion, e g lampblack.

(*d*) Dangerous reactions in contact with water, e g quicklime or with other substances, e.g nitric acid with charcoal or straw

(*e*) Explosion

2. **Spreading and contributory risk** includes—

(*a*) Spreading fires by migrating vapours or flowing liquids, e g petrol, oils, or melted solids, e g. tallow

(*b*) Inflammable matter generally

(*c*) Oxygen carriers, which intensify a fire, e g. nitrates and chlorates of potash and soda

(*d*) Substances which retard extinguishment by

i Precluding the use of water, e.g carbide of calcium, metallic powders

ii Giving off poisonous gases or noxious fumes, e g. acids, sulphur.

3. **Susceptibility risk.** Where goods are easily damaged by smoke or water a heavy loss may result from even a small fire in a building in which they are stored, e g. tobacco Sometimes water damage can be avoided by the use of carbon dioxide for extinguishment.

Whenever possible hazardous goods should be stored separately from those which are non-hazardous, not only to prevent a fire spreading to the latter, but also to avoid the smoke and water damage which they might sustain during a fire in the hazardous goods Warehouses, where large values are probable, should be separated from factories and workshops, where fires are more likely to start, raw materials should be stored apart from

finished stocks When separate storage is not possible there are usually several rather obvious precautions to be taken, e g. foodstuffs should not be stored where they are likely to be contaminated by poisonous vapours or noxious odours given off from other goods on fire, substances which react with one another giving off heat should be kept apart—in this category are acids and alkalis, oxygen carriers and combustible materials, and so on Goods should be so stacked as to permit easy access by fire-fighters, e g in small stacks separated by gangways and having a clear space between the top of the stacks and the ceiling. The intensity of a fire depends to a large extent on the calorific value of the goods stored, e g the calorific value—the heat latent in a cubic foot—of coal is twice, and that of some oils three times that of wood Briefly, the precautions to be observed in storage are those necessary (1) to avoid the inception of a fire, and (2) to avoid a heavy loss should a fire occur.

The following notes indicate briefly the hazards of the more common hazardous goods References are made to the pages on which the hazards are more fully considered.

Acetone. Highly inflammable volatile liquid See Chapter VIII

Acetylene. Inflammable and explosive gas See pages 82–85

Acids give off noxious fumes when heated and thus seriously retard fire-fighting. Usually stored in carboys of glass or earthenware, which are liable easily to be broken, when the escaping acid itself may injure firemen or destroy, by reason of its corresive effects, goods stored near Chromic acid may cause fire if in contact with combustible substances Sulphuric acid (vitriol) must be kept away from chlorates and organic matter Nitric acid may initiate fire if in contact with hay, straw, charcoal, or oil of turpentine Hydrocyanic (prussic) acid is both inflammable and very poisonous A general precaution for acids is to store them in a cool place in such a manner that the containers are protected from breakage, and as far as possible from organic matter and oxygen carriers

Alcohols. Inflammable liquids See Chapter VIII

Anthracene. Coal distillation product used for making dyes Inflammable as a liquid (creosote), less hazardous as crystals

Benzene (or benzole), coal tar derivative, and benzine, petroleum derivative Inflammable liquids. See Chapter VIII.

Bleaching powder (chloride of lime), in contact with acids or even with damp air, evolves chlorine gas—not inflammable, but suffocating and liable to hamper firemen When exposed to heat, it liberates oxygen so freely that the containing vessel may burst, and the oxygen intensify a fire

Butane. Inflammable gas See p 81

Calcium carbide is made by chemically combining coke powder and lime in an electric furnace at a temperature of 3000° C. It will not burn, but moisture, even the moisture of the air, will cause it to give off acetylene—a most dangerous gas. See pp. 82–85

Camphine. Rectified oil of turpentine. Inflammable liquid, should be kept away from cotton waste, sawdust, lampblack, and nitric acid.

Camphor is a solid substance, obtained from camphor-tree oil, used in the manufacture of celluloid and as a preventive against moths Inflammable and aids combustion of articles treated with it

Carbon disulphide. Highly inflammable, volatile and poisonous liquid. See Chapter VIII.

Cellulose solutions contain cellulose nitrate and solvents which give off inflammable vapours. See Chapter X.

Celluloid. Very inflammable. May give off explosive vapour See Chapter X

Charcoal. Liable to spontaneous combustion. See page 44

Chlorates of soda and potash. See oxygen carriers

Coal. Liable to spontaneous combustion See pages 45 and 117

Collodion is pyroxylin dissolved in ether or alcohol It is a highly inflammable liquid (flash point 25° F) used in photographic material factories and some artificial silk works Pyroxylin (collodion cotton) is an explosive, but when stored wet or in solution in alcohol and contained in airtight cases is not regarded as within the scope of the Explosive Acts See Chapter X.

Creosote. Oily distillate from coal tar or wood Various grades, most of them inflammable

Elektron. A magnesium alloy. The swarf is inflammable and the dust—mixed with air—explosive. See page 135

Ether. Highly inflammable and volatile liquid See Chapter VIII

Explosives. Gunpowder is a mixture of saltpetre, sulphur, and charcoal. **Gun cotton** is made by treating purified cotton waste with nitric and sulphuric acids. **Nitroglycerine** is prepared by the action of a mixture of nitric and sulphuric acids upon glycerine. It is used in the form of dynamite, in which it is mixed with siliceous earth. Very many kinds of explosives are in use, but nearly all are nitro compounds, i e. similar to gun-cotton or nitroglycerine Great care is necessary in their manufacture, storage, and use. Most are exploded by detonation, for which purpose detonators are used. **Detonators** are almost invariably fulminate of mercury, a substance which when dry explodes if struck or heated Fog signals, coloured fires, cartridges, etc , are all classed as explosives.

Where explosives are stored, there is the probability of an explosion should a fire occur Apart from actual damage caused by the explosion, burning fragments may be flung considerable distances and the fire extended Where explosives are manufactured the premises consist of small detached sheds of fragile construction, so that an explosion in one will not affect the others. Elsewhere, only small quantities should be kept.

Fancy goods are generally flimsy and inflammable

Fire lighters. Clearly these are hazardous, as they are made to burn Usually consist of wood, shavings, sawdust, or cardboard soaked in tar, mineral oils, or naphthalene They should be stored in a detached shed or in metal bins

Fireworks are made from gunpowder, sulphur, charcoal, and nitrate or chlorate of potash. These are all hazardous goods separately or in combination. Fireworks containing both sulphur and a chlorate are not allowed in this country. Where small quantities are kept in shops for sale in November they should be stored in metal cases The hazards arising from carelessness in use are obvious

Gases, compressed in steel cylinders. Should a fire occur where any of these are stored, an explosion may result from the excessive pressure caused by the heat, or at any time leakage may occur if the cylinders or their valves become damaged Compressed "permanent" gases so stored include carbon monoxide, coal gas, hydrogen, methane, all of which are lighter than air liquefied gases include ethylene (lighter than air), ethyl chloride, and methyl chloride (heavier than air). All these gases are inflammable and will form explosive mixtures with air In fires the cylinders should be kept cool by copious supplies of water at low pressure. For acetylene see page 85, oxygen, page 133, and calor gas, page 81

Lampblack. Liable to spontaneous combustion, especially if damp, or if vegetable or animal oil, grease, or sulphur is allowed to come into contact with it See page 45.

Lime. Quicklime is made by heating limestone It does not burn, but when wetted, even by rain or dew, develops great heat, sufficient to ignite easily combustible matter near it, e g. empty bags, straw, or a wooden platform on which it may be standing. Slaked lime, i e quicklime which has been "slaked" by wetting, is not hazardous

Magnesium. The swarf is inflammable and the dust—mixed with air—explosive. See p 135

Matches. Lucifer (strike anywhere) matches should be stored in metal-lined cases and safety matches either similarly or in stout wooden cases In these conditions the risk of a fire

originating is small, but fuel would be added to an existing fire.

Metallic powders (often termed "bronze powders") include powdered iron, copper, zinc, magnesium, bronze, and aluminium Liable to spontaneous combustion, especially if damp, and to be explosive if mixed with air in the form of a dust cloud, or with oxygen carriers Water must not be used to extinguish a fire involving them, asbestos graphite, powdered asbestos, or dry sand should be gently applied to smother the fire and not disturb the powder.

Mungo and shoddy are made by tearing up rags and woollen waste, subsequently to be used with new wool in manufacturing woollen cloth Mungo is made by grinding hard rags such as suitings, shoddy from soft rags such as underclothing or shawls. In each case the rags, before being ground, are dressed with oil, and the material will burn freely Owing to the cotton fibres present there is a possibility of spontaneous combustion.

Naphtha and benzene. A general term including distillates of mineral, rock and tar oils and wood naphtha (methyl alcohol) having flash points up to about 70° F. Inflammable liquids. See Chapter VIII.

Naphthalene in the form of crystals is obtained during coal-tar distillation. Used in connection with dye colour making, for manufacturing firelighters in combination with sawdust or shavings, and by furriers as a means of preserving furs against moths Naphthalene is inflammable when heated, especially the crude crystals, the refined product being less dangerous.

Nitrates of soda and potash. See Oxygen carriers.

Oils may be considered in three classes Essential oils, fixed oils, and mineral oils.

Essential (or ethereal) oils comprise volatile oils occurring in various parts of plants, chiefly scent-bearing and flavouring products, e.g lavender, cinnamon, rosemary, peppermint, clove, lemon, juniper, aniseed, camphor, eucalyptus, and turpentine oils. These oils are more dangerous than fixed oils and will burn without a wick. Turpentine is dealt with more fully under that heading Artificial perfumes often contain, in addition, inflammable spirits, and are generally more hazardous than natural essential oils

Fixed oils, i e. animal and vegetable oils and fats. There is no well-defined difference between fats and oils, the former being rendered liquid by heating Animal oils include neat's-foot oil, lard, tallow, cod-liver, shark, whale, and porpoise oils, vegetable oils, olive, almond, castor, palm, and coconut, all non-drying oils, and cotton, linseed, poppy, hempseed, tung, rape, or colza, all drying oils. Apart from the risk of spontaneous combustion,

which is vitally affected by the drying properties of the oils (see Chapter VII), there is little difference in the fire hazard of these oils

Their flash points are high All those mentioned are over 400° F. except rape, which is about 320° F , and they are, therefore, not so easily ignited as the majority of mineral oils. Once alight they burn freely and fiercely, and are difficult to extinguish, as they float on water, the use of which may thus extend the area of the fire. Water applied to fiercely burning oil or fat will cause a kind of explosion, in which water and burning fat are widely scattered The risk from these oils is greatest when they are soaked up by combustible materials, wood floors, waste, fabrics, sawdust, etc , when an inflammable mass is formed.

Mineral and rock oils (hydrocarbons) include petroleum, which is obtained from natural reservoirs beneath the earth's surface, and oils obtained by distillation from bituminous coal or shale Unlike animal or vegetable oils they are not liable to spontaneous combustion , the risks arise from their low flash points. See p. 48

Oilcakes. Liable to spontaneous combustion.

Oxygen carriers. A fire burns more fiercely when oxygen is supplied to it by a draught of air, and, for the same reason, it is intensified if oxygen is supplied by any other means. An oxygen carrier is a chemical compound, including in its composition a large proportion of oxygen, which it will release on the application of a moderate heat The more important oxygen carriers are—

Chlorate of potash, chlorate of soda, nitrate of potash (nitre or saltpetre), nitrate of soda (cubic nitre or Chili saltpetre), nitrate and perchlorate of ammonia, nitrate of lime, used as artificial manures, and in dye works and explosive factories

The fire hazards are similar in each case—that, on being heated, oxygen is evolved, that an explosion is probable on coming into contact with burning matter or if water is applied while red hot, that nitric and sulphuric acids in contact cause violent reactions Mixtures of sulphur and chlorates or nitrates are violently explosive Chlorates are the more dangerous, and a mixture of chlorate of potash and combustible matter, e g if scattered on a wooden floor or mixed with sawdust and straw, etc , can very easily be ignited. A few years ago a serious explosion was caused in such circumstances by a spark from a workman's boot on a stone floor Empty bags, having contained nitrates, are hazardous, as some nitrate is left between the fibres of the bag and intensifies the likelihood of the fibre spontaneously igniting, especially if damp. Since oxygen carriers do not themselves burn, but are highly dangerous when in contact with any oxidizable matter, and intensify any fire in which they may

be heated, the most effective precaution is to store them in a separate building or fire-resisting room reserved for their exclusive storage

Of other oxygen carriers it may be noted that permanganates are liable to spontaneous combustion if acted on by sulphuric acid, that peroxides will cause spontaneous ignition of organic matter, and that bichromates, bromates, and perborates possess the general qualities of the class

Paints. See Varnishes

Petroleum. See Oils, mineral

Phenol (carbolic acid) gives off inflammable vapours when heated

Phosphorus, white, yellow, or stick, is spontaneously inflammable in air at ordinary temperatures, and therefore must be kept under water. When burning gives off dense white poisonous smoke Easily extinguished with water sprays or wet sand, but will reignite on drying Must be kept wet until removed

Amorphous, or red, phosphorus is a powder made from white phosphorus, but is much less hazardous; it is not spontaneously inflammable in air, but is dangerous in contact with oxygen carriers. Used in the manufacture of matches, etc

Pitch is the residue from the distillation of tar or petroleum. Used for road-making, caulking boats, and protecting timber against the weather. It does not ignite easily, but will burn freely when warm, giving off dense smoke

Plastics. The term includes a number of materials having very different properties, e g celluloid is highly inflammable, cellulose acetate will burn freely, "erinoid" and prodncts moulded from "bakelite" and similar powders are non-hazardous

Potassium (metallic) and sodium (metallic) will ignite explosively when heated or when water is applied Liable to spontaneous ignition in damp air Can only be stored under mineral oil or in airtight drums Water, carbon dioxide, carbon tetrachloride, soda acid or foam must not be used for attempts at extinguishment Dry sand is suitable

Printers' ink. Cleaning rags contaminated with ordinary printers' ink (which contains lampblack and linseed oil) are liable to spontaneous combustion, and should be kept in metal receptacles pending daily removal, sienna and ultramarine inks are considered specially hazardous Ordinary printers' inks do not give off vapours, but photogravure inks, and solutions for cleaning the rollers of machines used in this process, contain inflammable volatile solvents, and such inks should be stored outside the works, only sufficient for immediate needs being brought in at a time

Pyroxylin (collodion cotton). Inflammable See Chapter X.

Rags are used in connection with woollen manufacture for making mungo and shoddy. If all were clean the risk would be small, but a few oily cotton rags in a bale or heap may ignite spontaneously and fire the remainder, or a lucifer match mixed with the rags may be ignited by friction. Where rags are ground, precautions against dust explosions should be taken, and against foreign matter, e g buttons, likely to cause a frictional spark, being fed into the grinding machines

Resins and gums. Certain trees exude substances which form hard matter in contact with air These exudations, particularly those which are soluble in water, are known as gums Resins are gums which are soluble only in *chemical* solvents, e g turpentine, naphtha, methylated spirits Both are used for making varnishes, electric insulating materials, and have many other uses When heated they give off inflammable vapours, also much smoke, which may damage other goods. The dust of some resins mixed with air is explosive. Synthetic resins involve hazards in their manufacture, but the finished products are non-hazardous.

Rubber and rubber solution. Rubber is a gummy substance from certain orders of trees, and is used in the manufacture of waterproof cloth, boots and shoes, motor tyres, electric insulating materials, and many other articles Burning rubber flows at about 280° C, and while in a molten state gives off volumes of inflammable gas and clouds of noxious smoke Rubber fires are very difficult to extinguish Large volumes of water at high pressure are required

For ease of manipulation rubber may be dissolved in various chemical solvents The hazards of such solutions depend on the solvent employed the most hazardous are bisulphide of carbon or ether, but petroleum naphtha is more commonly used, and in all cases inflammable vapours are given off. Non-inflammable solutions, using carbon tetrachloride as a solvent, are manufactured, but as they are expensive they are not of wide practical application. Rubber "latex," which is practically incombustible, is now sometimes used in place of rubber solution.

The properties of synthetic rubbers differ, e g. some are non-combustible and some are electrically conductive

Sawdust is liable to spontaneous combustion if contaminated with vegetable or animal oil.

Seeds stored in silos swell to such an extent when water is applied that the walls may collapse. Care in extinguishment of fires, even those in adjoining buildings, is therefore necessary. Oily seeds (cotton seed, rape seed, linseed, etc.) are liable to heat

spontaneously, but whether ignition will occur in the absence of other material is doubtful.

Shoddy. See Mungo and Shoddy.

Sodium. See under Potassium.

Solvents. Many substances used in industry are not soluble in water, and chemical solvents are employed. Most solvents are inflammable, including bisulphide of carbon, ether, alcohols, methylated spirits, acetone, amyl acetate, turpentine, petroleum distillates, etc There are non-inflammable solvents, e g. carbon tetachloride, trichlorethylene, but they are not so widely used on account of their greater cost and toxic properties.

Spirits give off inflammable vapours See under Alcohol and Oils (petroleum)

Sulphur (brimstone) is usually kept in "sticks," or in powder form, known as "flowers of sulphur." It ignites readily and may, in burning, evolve inflammable vapours, or, in the form of dust, form an explosive mixture with air. Dangerous when in contact with oxygen carriers, e g chlorates and nitrates, friction being sufficient to ignite such mixtures. May ignite spontaneously in contact with lampblack• or charcoal Gives off noxious fumes when burning, and, owing to the low temperature at which it melts, may spread a fire by flowing It should, therefore, be kept on the lowest floor of the building in a separate compartment Used in making sulphuric acid, fireworks, rubber, and as an insecticide.

Tallow. Melted animal fat, used in soap- and candle-making, and by leather dressers. It is heated before use, and care must be taken that it does not boil over. Makes floors and surroundings greasy, and assists a fire to burn more fiercely. May spread fire by melting and flowing. Floats on water, with which it will not mix See Oils, fixed.

Tar is distilled from wood, peat, shale, and, most important, coal. It contains inflammable products, differing according to the source from which the tar is distilled, and therefore ignites easily and burns fiercely. When coal tar is itself distilled the following products, amongst others, are obtained—

Light spirits or oils, xylol, toluol, benzenes, and naphthas—middle oils, naphthalene, phenol—heavy oils, creosote, anthracene, all of which are hazardous, leaving a residue of pitch

Thermite is a mixture of iron oxide and powdered aluminium which when burning produces a very high temperature (about 2500° C.). Sometimes used for welding and also as a filling for magnesium incendiary bombs. Cannot be extinguished, either by water or by smothering

Turpentine. Crude turpentine is an ethereal oil combined with

resin obtained from certain trees When distilled, an oily spirit, oil of turpentine, is produced, leaving a residue of rosin (colophony) Oil of turpentine is used for making or thinning varnish, paints, etc , and is readily inflammable, having a flash point 90°–100° F It will ignite spontaneously in contact with strong nitric acid or with chlorine. Lighter than water, with which it will not mix.

Turpentine (or **turps**) **substitutes,** known as white spirit, are petroleum distillates Generally they have a slightly lower flash point (80°–90° F) than turpentine, and may therefore be more hazardous

Varnishes, lacquers, enamels, and paints are liquids which are used to give to a surface a protective and decorative coating.

Oil varnishes comprise linseed oil, resins, and turpentine. The fire hazard depends largely on the proportion of turpentine, as this has a flash point of about 100° F , while that of linseed oil is about 500° F. When once alight these varnishes burn freely. Rags soaked in oil varnish may be liable to spontaneous combustion.

Spirit varnishes, which include french polish, consist of resins dissolved in spirit, generally methylated spirit, but some naphtha may be used. Owing to the lower flash point these are more hazardous than oil varnishes.

Enamels are oil varnishes coloured by the addition of pigments

Paints vary considerably in their composition, but consist mainly of linseed oil, white or red lead, turpentine, and colouring pigments, and will burn freely once ignited. In paints employing synthetic resins, known as synthetic paints or lacquers, the solvents are highly inflammable and comparable to those used in cellulose paints

Cellulose paints, lacquers and varnishes are hazardous. See Chapter X.

All these varnishes, paints, etc , should be stored outside the main buildings, or in a fire-resisting compartment, and sufficient only for one day's use brought into the workshop at a time For extinguishment see pages 54–55

Vegetable fibres and grasses are all hazardous on account of their inflammable nature When loose they ignite easily and burn fiercely and when packed tightly the bales may smoulder for some considerable time before bursting into flames. Some fibres are also liable to spontaneous combustion (see Chapter VII).

Flax (linen, etc , manufacturing), *Hemp* (rope and sailcloth making), and *Jute* (sack and canvas making) are liable to spontaneous combustion if either oily or *damp*. *Hay* is liable to spontaneous combustion if stacked damp.

Cotton A most important fibre and one of the most hazardous. It will heat if packed damp, but does not ignite spontaneously from this cause If oily, with vegetable or animal oil, the risk of spontaneous combustion is greater than that of oil in conjunction with any other fibre

Other important fibres and grasses include—

Alpha, or alfa, esparto (for paper making), *bass or bast, coconut or coir fibre* (for mats), *bamboo fibre* (brush-making), *crin, diss, kapok* (stuffing and upholstering). These are not in themselves liable to spontaneous combustion, but if soaked in vegetable or animal oil may become hazardous in a similar, but lesser, manner to cotton, by reason of sufficient heat being generated by oxidation of the oil to ignite the fibre. Apart from the risk of spontaneous combustion any oily fibre is dangerous because of the ease and fierceness with which it burns

Fibres should be stored in a separate warehouse, but where this is not practicable care must be taken that oils or fats are not stored near, and that the fibre is not allowed to become wet. Smoking should be prohibited, and all possible sources of ignition eliminated Water is generally a suitable medium for extinguishing fibre fires, but there is one danger. the fibres swell on becoming wet, and in a warehouse tightly packed the swelling may be sufficient even to cause collapse of the walls.

Waste. Textile mill waste is oily, easily combustible, and liable to spontaneous combustion For waste generally see pages 37–39

Waxes may be the product of the animal, vegetable, or mineral kingdoms, the most important being beeswax and paraffin wax (ozokerite). They are lighter than water, melt on heating to a liquid state, and are combustible. As they are usually too hard to be used as they stand they are mixed with turpentine or other inflammable solvent and/or heated prior to use. Many fires have occurred due to the boiling over of waxes being heated over an open fire or gas-ring. Water must not be used in extinguishment, as the burning wax might be spread by floating on the water. Sand or foam extinguishers should be used..

Woodwool. Shredded wood used for packing purposes. Easily ignited and burns fiercely.

Xylol. Inflammable liquid, derived from tar and used as a solvent

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